Proceedings of an International Workshop on Current Environmental Issues of Fertilizer Production

Organized by the International Fertilizer Development Center

In cosponsorship with EFMA, IFA, TFI, UNEP, UNIDO, and USAID

June 7-9, 1999
Prague, Czech Republic
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Prague, Czech Republic
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IFDC publications are listed in *IFDC Publications*, General Publication IFDC—G-1, which is available free of charge.
During the past decade, the global fertilizer industry has made substantial progress in the identification and mitigation of potential environmental impacts that may occur at the point of production and throughout the physical distribution system. During this time, fertilizer producers, engineering and scientific community, fertilizer distributors and marketers, financial planners and managers, policy makers, and others who are charged with the management and regulation of environmental affairs within the fertilizer sector have accumulated a wealth of knowledge.

The environmental challenges currently confronting the fertilizer industry have increased in recent years and now include such issues as climate change and depletion of the ozone layer. Likewise, several international environmental Conventions now affect industrial operations and many of the environmental issues are interconnected. Thus, the adoption of more sophisticated approaches to environmental management, including the concept of pollution prevention, are now being rapidly adopted with planners, managers, operators taking on an increased level of responsibility for mitigating environmental impacts.

Concurrent with the increased level of environmental sensitivity, complexity, and stewardship that has occurred within the industry during the past decade, there has been an unprecedented change in the structure of the industry. These structural changes have resulted in a significant consolidation of industry ownership, a decreased number of operating plants, and an accelerated shift from public to private-sector ownership and management. Despite the restructuring and consolidation of the industry, global production of fertilizer continues to increase and the environmental issues continue to be vigorously addressed in terms of technology, economics, and policy.

In view of the technological progress made worldwide in achieving an increased level of environmental stewardship in the fertilizer production sector, an appraisal of the fertilizer production industry in Central and Eastern Europe as it responds to existing and emerging environmental challenges is timely. IFDC organized an international workshop to provide the industry and other stakeholders an opportunity to examine the environmental issues facing the fertilizer production industry with emphasis on Central and Eastern Europe. This workshop was conducted in cooperation with the European Fertilizer Manufacturers’ Association (EFMA), the International Fertilizer Industry Association (IFA), The Fertilizer Institute (TFI), the United Nations Environment Programme (UNEP), the United Nations Industrial Development Organization (UNIDO), and the United States Agency for International Development (USAID).

These proceedings record the substance of the workshop deliberations. The reader of these proceedings may also wish to refer to the proceedings of other environmental workshop initiatives undertaken by IFDC:

- Environmental Impact of Ammonia and Urea Production Units, IFDC SP-17, 1992
- Phosphate Fertilizers and the Environment, IFDC SP-18, 1992
- Nitric Acid-Based Fertilizers and the Environment, IFDC SP-21, 1994
- Environmental Challenges of Fertilizer Production—An Examination of Progress and Pitfalls, IFDC SP-25, 1998

These publications may be obtained from IFDC.

James J. Schultz
Donald R. Waggoner
Technical Editors
Acknowledgments and Thanks

IFDC, as the organizer of this workshop, wishes to express its deep appreciation to the large number of invited speakers and delegates who gave so freely of their time and resources to make this event possible. For their assistance in cosponsoring and organizing this workshop, we also wish to thank the European Fertilizer Manufacturers’ Association (EFMA), the International Fertilizer Industry Association (IFA), The Fertilizer Institute (TFI), the United Nations Environment Programme (UNEP), the United Nations Industrial Development Organization (UNIDO) and the United States Agency for International Development (USAID). Finally, we wish to thank host country sponsor AGRA CZ a.s., represented by Mr. Jiri Kopenec, General Director and Chairman, and Mr. Zdenek Vybiral, Marketing and Development Advisor, for the in-country logistical support they so generously provided during the organization and implementation of the workshop.

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The United States Agency for International Development (USAID) is acknowledged
with thanks for their funding support that helped make this workshop possible.
The organizers of this workshop are deeply indebted to AGRA CZ a.s., represented by Mr. Jiri Kopenec, General Director and Chairman and Mr. Zdenek Vybíral, Marketing and Development Advisor, for the in-country logistical support they so generously provided during the organization and implementation of this workshop. AGRA CZ a.s. was incorporated in 1997 as a joint stock company. However, its roots can be traced back to 1927 when its predecessor company began producing fertilizer from animal horns and hooves. Today, AGRA CZ a.s. is still the largest processor of animal horns and hooves in Europe, while also being a leader in the production of foliar fertilizers and a large family of garden fertilizers.
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Welcome and Opening Remarks

A. H. Roy
President and Chief Executive Officer
International Fertilizer Development Center (IFDC)

On behalf of IFDC and the co-sponsors of this workshop, it is my pleasure to extend to you a warm welcome to Prague and to this International Workshop on Current Environmental Issues of Fertilizer Production. The co-sponsors of this workshop are the European Fertilizer Manufacturers’ Association (EFMA), the International Fertilizer Industry Association (IFIA), The Fertilizer Institute (TFI), the United Nations Environment Programme (UNEP), the United Nations Industrial Development Organization (UNIDO), and the United States Agency for International Development (USAID). This is the fifth IFDC international workshop designed to examine the impact of fertilizer production and use on the environment.

The first Workshop—Environmental Impact of Ammonia and Urea Production Units—was held in Mumbai, India, in March 1991 and focused on the environmental issues of ammonia and urea production. That 1-week workshop was attended by 80 delegates from 10 countries.

The second Workshop—Phosphate Fertilizers and the Environment—was held in Tampa, Florida, U.S.A., in March 1992. Discussions focused on the environmental impact of the production and use of phosphate fertilizers. Ninety-one delegates from 19 countries participated in the 1-week event.

The third Workshop—Nitric Acid-Based Fertilizers and the Environment—was conducted in Brussels, Belgium, in June 1993. That 1-week workshop was attended by 66 delegates from 26 countries.

The fourth Workshop—Environmental Challenges of Fertilizer Production, An Examination of Progress and Pitfalls—was held in Atlanta, Georgia, U.S.A. in September 1997. This 3-day event was attended by 68 delegates from 26 countries.

Why This Workshop?

During the past decade, substantial progress has been made in the identification and mitigation of any harmful impact that the production and distribution of fertilizers may have on the environment. During this time, a wealth of knowledge has been accumulated by the fertilizer producers, engineering and scientific community, fertilizer distributors and marketers, financial planners and managers, policymakers, and others charged with the management and regulation of environmental affairs within the fertilizer sector.

The environmental challenges currently facing the fertilizer industry now include such issues as climate change and depletion of the ozone layer. Likewise, a number of international environmental conventions now affect industrial operations, and many of the environmental issues are known to be interconnected. Thus, more sophisticated approaches to environmental management, including the concept of pollution prevention, are now being rapidly adopted by those involved in the fertilizer sector.

Along with the increased level of environmental sensitivity, complexity, and stewardship of the last decade, there has been an unprecedented change in the structure of the industry, resulting in a significant consolidation of industry ownership, a decreased number of operating plants, and an accelerated shift from public- to private-sector ownership and management. Despite these changes, global production of fertilizer continues to increase and the environmental issues continue to be vigorously addressed in terms of technology, economics, and policy.

In view of this rapid progress and emerging issues, one of the recommendations of the workshop held in Atlanta in 1997 was to organize regional workshops to focus on regional issues. To this end, IFDC, in cooperation with our cosponsors, is pleased to provide the industry and other interested parties an opportunity to participate in this first regional workshop, which focuses on an analysis of the environmental
issues facing the fertilizer production industry in Central and Eastern Europe. This region was selected for this first regional workshop due to its very important role in the world fertilizer production sector.

**Workshop Content**

The workshop deliberations will include an inaugural session and six technical sessions. The technical sessions will focus on the following subjects: (1) Industry Overview and Specific Environmental Issues in Central and Eastern Europe; (2) Pollution Prevention and Waste Minimization; (3) Environmental and Quality Management Systems; (4) Technical Assistance, Training, and Communication for Improved Environmental Stewardship; (5) Environmental Codes of Conduct and Stewardship Through Engineering and Technology; and (6) An Examination of the Broader Environmental Issues.

We trust the workshop deliberations will be stimulating and will lead to the identification of additional steps that may need attention. The usefulness of the deliberations will depend largely on the contributions from each of you during the question, answer, and discussion sessions. The organizers of this workshop are deeply indebted to AGRA CZ a.s., represented by Mr. Jiri Kopenec, General Director and Chairman, and Mr. Zdenek Vybiral, Marketing and Development Advisor, for the in-country logistical support they so generously provided during the organization and implementation of this workshop. Again, I want to welcome all of you to the workshop.
I must start by passing on the apologies of EFMA’s Director General, Helmuth Aldinger, who was scheduled to be here today but had to change his plans due to a last-minute urgency. He very much regrets not being here and meeting all of you, but he sends his best wishes for a successful meeting.

For those of you who are not familiar with our organization, EFMA represents the major fertilizer manufacturers in Western Europe, acting as “watchdog” by anticipating and preparing for issues that may affect the industry, promoting the role of fertilizers in European agriculture, and providing our members with a wide range of statistical information and studies. Our members account for some 90% of Western Europe’s nitrogen fertilizer production capacity and some 70% of phosphate fertilizer production.

As you are probably aware, EFMA has a long-standing tradition of openness towards Eastern Europe. Since January 1997, we have enjoyed and benefited from the commitment and participation of our members in Poland and the Czech and Slovak Republics in our technology and agriculture committees. We have an active program of enlargement, encouraging producers from countries preparing for European Union (EU) accession to join us. EFMA can be instrumental in assisting these producers in their efforts to procure the “acquis communautaire” required by aspiring member states.

We began a concerted effort in 1994 to bring together producers from Eastern and Western Europe to exchange views and information. Until 1998 we staged an annual “East-West Seminar.” In 1998 we were also pleased to welcome Mr. Rimantas Sinkevicius from Achema in Lithuania to spend some time with us, discovering the ins and outs of life and work in EFMA and Brussels. This year, in a more comprehensive program, we have invited representatives from middle management of Central and Eastern European producers to come to Brussels for 3 weeks. They will spend time with us learning how EFMA works and find out more about the European institutions, meet some of EFMA’s contacts, and visit the Commission and Parliament.

Four “upwardly mobile” participants from Poland and the Czech and Slovak Republics have signed up for our upcoming summer course: an investment from both sides in a common future.

We are delighted to see that IFDC is continuing EFMA’s tradition in bringing East and West together. I would like to wish each of you every success in the workshop activities of the coming days.
Opening Remarks

L. M. Maene
Director General
International Fertilizer Industry Association (IFA)

It is with great pleasure that, on behalf of the International Fertilizer Industry Association (IFA), I welcome you to this important international workshop—important because it deals with environmental issues faced by the fertilizer industry. Following the success of the 1997 environmental workshop in Atlanta, it is most appropriate that this event is being held in Prague, in the heart of Central Europe where the fertilizer industry is striving hard to meet international standards of environmental management within the shortest possible time. IFA is proud to be associated with this event, which is perfectly in line with its strategic objective of supporting the development and use of environmentally sustainable techniques for the manufacture of fertilizer.

For those of you who are not familiar with our organization, IFA is a nonprofit industrial organization that has about 500 member companies in over 80 countries. IFA promotes actively the efficient and responsible production, transport, and use of all plant nutrients to maintain and increase agricultural production worldwide in a sustainable manner.

I wish to thank IFDC for taking the initiative to organize the workshop and the other sponsors for their assistance and cooperation in this initiative.

Finally, I wish you every success in your deliberations, and I look forward to the conclusions of this workshop, which will determine the future steps to take.
The fertilizer industry represents a nexus for a range of U.S. Government and United States Agency for International Development (USAID) interests in Eastern Europe and the former Soviet Union including privatization, trade, technology, crop production, and environmental protection—the latter encompassing fertilizer production, handling, and on-farm use. Under the communist command economies, the fertilizer industry was universally and totally government-owned, and today it remains one of the industries proving most resistant to the privatization process. The production technologies employed tend to be inefficient and environmentally unfriendly; fertilizer has frequently been exported at subsidized rates in order to earn badly needed foreign exchange; and with the near-total breakdown of the former farm input delivery systems, fertilizer use throughout the region has plummeted, resulting in reduced agricultural production and farm incomes.

It is this conjunction of issues and opportunities, and especially the production/technology/environment interface, that prompted USAID interest in co-sponsoring and financially supporting this workshop. Private-sector investment will be crucial to improving the efficiency and environmental soundness of fertilizer production, and increased fertilizer production and use are crucial to increasing agricultural production and farm incomes. Thus, focusing on this particular area can have far-reaching benefits. We anticipate that this interest in fertilizer-related issues will continue on a regional basis, even following the completion of USAID’s assistance programs in most countries in the region.

We are confident that the agenda and deliberations of this workshop will bear fruit in the form of ideas, dialogue among participants, and actions to enhance the safety, environmental soundness, and productivity of the fertilizer industry in the region. We applaud IFDC’s initiative in making it all happen.
Keynote Address:
Challenges Facing the United States Fertilizer Industry

Gary D. Myers
President
The Fertilizer Institute (TFI)

Introduction

Thank you for asking me to join you here in Prague for this very informative gathering. I would like to commend the management and staff of IFDC for having the foresight to organize several of these types of workshops. They represent an excellent demonstration of the world fertilizer industry’s ability to cooperate on efforts to produce fertilizer efficiently without harming the surrounding environment.

By looking at environmental issues as a group—rather than as individual companies or countries—perhaps we can reach some level of agreement on sound stewardship practices for the future. While the purpose of this workshop is to discuss specific measures the industry can take, I have been asked to provide an overview of the challenges facing the U.S. fertilizer industry along with a short summary of how The Fertilizer Institute (TFI) and its member companies are working to meet them.

Before I go further, I would like to say a few words about the many changes being brought about by the Internet’s increasing presence in all our lives. This incredible tool allows me to find out what IFDC is doing across the world with just a few clicks of the mouse. It also allows speedy communication between people and companies from different points on the globe. Our TFI website regularly generates inquiries from all over the world. For better or for worse, the Internet has fundamentally changed the way we do business. Environmental groups and communities can now find and send information with just a few clicks. People who had little or no opportunity to ever meet face-to-face now regularly communicate among themselves and with companies. Pursued creatively, it is a fantastic asset; ignored, it is an incredible liability.

A search for “fertilizer” on the Internet will show the many U.S. rules and regulations governing production practices for fertilizer. The federal government, many states, and ordinary citizens have some say in how our production plants operate. Air, water, and underground emissions are just some of the issues TFI’s member companies must address in order to operate legally in the United States.

Risk Assessment

Fortunately, there is another method now being used by a majority of regulatory agencies in the United States. It’s called “risk assessment,” and, quite simply, it involves assessing the “risk” a particular substance poses to either human health or the environment. For many reasons, it is better suited to the fertilizer industry than the old “best available technology” method ever was. Because this “risk assessment” method is being used by regulators and because there are no data specific to fertilizers, TFI has initiated research to generate these data.

The TFI research includes a risk assessment on safe levels of non-nutritive elements. This screening level assessment establishes safe risk-based concentrations for four metals—
arsenic, lead, cadmium, and mercury. The study examines the risk of these metals in fertilizers to applicators—both farmers and professional applicators. This study, along with another done by the State of California, finds the level of metals in fertilizers to be well below risk levels.

Additionally, we have commissioned a comprehensive risk assessment to examine 14 different non-nutritive elements in 26 different fertilizer products. We will have the results of this survey in hand by the end of this year.

The current findings of our risk assessment project can be found on our Internet site—www.tfi.org—and I encourage you and your colleagues to follow our risk assessment progress on the Internet.

To understand why we are conducting this risk assessment work on fertilizer, it is helpful to know about the political and environmental situation in the United States. Almost 30 years ago, the U.S. Environmental Protection Agency (EPA) was formed. As an agency of the federal government, EPA, as we call it, initially had jurisdiction over companies' activities as they affected our nation's air, water, and soil. As a result, EPA regulates every potential environmental aspect of fertilizer production in the United States—from air to water.

Recently, however, two forces have dramatically changed the range and the scope of EPA's activities:

- A change in focus toward regulating "nonpoint" sources of pollution.
- Greater community involvement in environmental issues.

Many years ago, when the public was first made aware of the importance of the environment, the spotlight was entirely on the manufacturing community. Today, almost 30 years later, the focus has shifted somewhat to "nonpoint" pollution in addition to the traditional risk assessment issues I have just outlined.

In the United States, farmers are viewed as the "last unregulated industry" and, as such, are under increasing scrutiny to demonstrate their efforts to ensure that the environment is unharmed despite their activities. New rules on "total maximum daily loads" of nutrients are just one example of the government's increasing efforts to dictate fertilizer use practices to farmers.

**The Expanding Role of the Public**

When EPA was established it was largely due to the public's call for greater corporate accountability for the environment. From that initial push toward public involvement, we have seen a steady and strong increase in the role of the public's opinion in ensuring the environment is kept clean.

Today, for example, TFI's member companies are required to report, on an annual basis, all emissions to the federal government. Having gathered that information, EPA then publishes an extensive list of the companies whose releases are highest in each state and nationally. This list is called the "toxic release inventory."

Having been given this information, the public can then utilize it to pressure individual companies to be better stewards of the environment by reducing so-called "toxic" emissions. Unfortunately for our industry, the public tends to apply the "toxic" label to all emissions, even those that are not toxic. As you might have guessed, toxic or not, just by virtue of being on the list, our products may be viewed negatively by the public.

Recently, environmental organizations in the United States have used the kind of environmental information released by the government to generate their own "reports" detailing the perceived wrongs of manufacturing companies. A new Internet site, funded at a cost of $1 million, now details the risk individual chemical production facilities pose to the people living in the areas around them. Fertilizer production facilities are, of course, included on this site.

**Shifting the Burden**

What seems to have happened is that the U.S. government, in its attempt to spend less on regulation, is shifting the burden of enforcement to the public. And it is working. Communities are becoming more involved in the everyday activities of manufacturing facilities of all kinds. Today, U.S. companies who want to stay in business must concern themselves not only with government regulations, but also with what the public thinks. Moreover, because public opinion is the result of many forces and, as such, subject to change, we are very much at the mercy of environmental groups and the media in addition to the government regulators with whom we are already accustomed to dealing.

**Conclusion**

Our industry is currently working to comply with a new EPA rule that expands community involvement in the operations of fertilizer plants nationwide. The rule, which becomes effective later this month, is called the "Risk Management Program Rule" and requires fertilizer manufacturers to communicate the potential impact of a "worst case scenario" accident. Think for a moment about how you would describe the result of
an airplane crashing on your ferti-

tilizer facility and destroying storage tanks, along with all your containment structures.

Whether expanding a production plant or planning for an emergency, we must include the public almost as though they are our business partners. I strongly believe this is a trend that ultimately will travel far beyond the United States. As environmental concerns and regulations evolve, the involvement of citizens will emerge as a force in the environmental compliance process.

As you work here in Prague to examine the crucial issues facing the Central and Eastern European fertilizer industry, remember some of these “macro” issues we will all ultimately face in the years to come. I would not be so bold as to suggest that all environmental regulations start in the United States—but I do believe environmental trends are not national or regional but worldwide in nature.
The Fertilizer Industry of Central and Eastern Europe

K. F. Isherwood
Head of Information and Market Research Service
International Fertilizer Industry Association (IFA)

Introduction

This paper is divided into two parts: the first concerns the countries of the former Soviet Union (FSU), i.e., the Commonwealth of Independent States (CIS) and the Baltic States; the second concerns the countries of Central and Eastern Europe (CEE). A discussion of the fertilizer situation in these two regions of Central and Eastern Europe follows.

The Former Soviet Union

The FSU comprises the 12 CIS countries and the 3 Baltic countries. The CIS comprises the Russian Federation, Ukraine, Belarus, Uzbekistan, Kazakhstan, Georgia, Azerbaijan, Moldova, Kyrgyzstan, Tajikistan, Armenia, and Turkmenistan. The Baltic countries are Estonia, Latvia, and Lithuania. The Russian Federation accounts for 77% of the territory, 70% of the natural resources, and 52% of the population of the FSU.

In 1996 the population of the CIS amounted to 285 million and that of the Baltic region, 8 million. The highest population is that of Russia (148 million) followed by that of Ukraine (51 million), Uzbekistan (22 million), Kazakhstan (16 million), and Azerbaijan (8 million). The other states each have a population of between 4 and 6 million.

The very intensive cultivation of irrigated cotton, with a high water demand and heavy applications of not only fertilizers but also plant protection products, has contributed to the environmental problems of the Aral Sea. Water destined for the Aral Sea has been almost completely diverted by irrigation.

The gross domestic product (GDP) of all the states of the CIS is lower today than it was in 1989. Uzbekistan and Belarus have fared best, with GDPs at 70% or more of their 1989 level. The GDPs of Russia and Ukraine are 50% or less of their 1989 level. As can be seen in Table 1, Uzbekistan and Belarus have also maintained the highest rates of fertilizer consumption.

Fertilizer Production and Exports

The relative importance of the FSU as a world producer and exporter of fertilizer materials and products is shown in Table 2. Ukraine, a major fertilizer producer and exporter, is dependent on Russian natural gas but controls major export ports.

The relative importance of Russia and Ukraine as producers of fertilizer materials is shown in Table 3. In addition, in 1997 Belarus (producing 50% of FSU potash), Lithuania (12% of the ammonium phosphate), and

<table>
<thead>
<tr>
<th>Country</th>
<th>Population (million)</th>
<th>Agricultural Area (million ha)</th>
<th>Fertilizer Rate (kg/ha)a,b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia</td>
<td>148</td>
<td>214</td>
<td>16</td>
</tr>
<tr>
<td>Ukraine</td>
<td>51</td>
<td>41</td>
<td>21</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>22</td>
<td>5c</td>
<td>455 (cotton)</td>
</tr>
<tr>
<td>Belarus</td>
<td>10</td>
<td>9</td>
<td>147 (arable)</td>
</tr>
</tbody>
</table>

a. N + P2O5 + K2O.
b. For comparison: France 190 kg/ha, Germany 176 kg/ha, United States 138 kg/ha.
c. 4.3 million ha is irrigated.

1. Presented on behalf of M. Malinowski, Chairman, Zaklady Azotowe Pulawy S.A., Poland, and IFA Vice-President for Central and East Europe.
The price of natural gas to Ukraine has declined, but the cost of natural gas transporta-
tion has increased. The Ukraine industry is still state owned and partially protected.

The domestic prices of finished fertilizers in Russia are attractive to producers, perhaps more so than those for export, but the domestic market has difficulty in financing purchases. The fertil-
izer producers are owed large sums by the agricultural cooperatives, which themselves have liquidity problems.

- **Urea**—Urea exports from the FSU declined by 14% in 1997 with substantially reduced ex-
ports from Russia. In 1998 urea exports from Russia sta-
bilized, but total FSU exports declined by 5% due to a decline in exports from Ukraine. In 1998, 84% of the urea produc-
tion was exported; ammonium nitrate is the nitrogen fertilizer of choice in the domestic market.

- **Ammonium Nitrate/Calcium Ammonium Nitrate (AN/ CAN)**—AN/CAN exports fell from 1.4 mt N in 1996 to 1.1 mt N in 1997. AN can now be transported in bulk for bagging
at the port of export or exported in bulk. In 1998, Russian ex-
ports of AN increased by 7%.

- **Processed Phosphates**—In 1992 FSU exports of mono-
ammonium phosphate (MAP) were substantial, often at a very low price. Since then ex-
ports have decreased due to the increasing cost of energy and transport. In addition to high energy and transport costs, producers also have to cope with the costly transport of phosphate rock and sulfur. Several plants are idle. Annual MAP exports today amount to about 1.0 mt P2O5. In addition, Russian exported 0.40 mt P2O5 as diammonium phosphate (DAP) in 1998 compared with 0.35 mt P2O5 in 1997. This increase is perhaps indicative; there could be an increase in Russian MAP and compound (NPK) fertilizer production and exports in future years, espe-
cially in view of the growing market for compound fertili-
izers in China.

Total Russian production of all phosphate fertilizers reached 1.7 mt P2O5 in 1998.

**Uzbekistan (16% of the ammonium nitrate/calcium ammonium nitrate)** were significant fertili-
zer producers in the FSU.

**Nitrogen**—Russia has 37% of the world’s natural gas reserves and from that point of view is well placed to produce nitrogenous fertilizers at a competitive price. However, it is difficult to know the exact cost of natural gas to Russian fertilizer producers because several factors are involved. Also, a number of fertilizer producers continue to produce and export fertilizers without paying for the natural gas or paying for only part of natural gas deliveries. They stay in business for social reasons.

**Table 2. FSU Fertilizer Production and Exports (1998)**

<table>
<thead>
<tr>
<th>Product</th>
<th>Production</th>
<th>Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>- (% of world total) -</td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>12</td>
<td>34</td>
</tr>
<tr>
<td>Urea</td>
<td>7</td>
<td>27</td>
</tr>
<tr>
<td>AN/CAN</td>
<td>21</td>
<td>27</td>
</tr>
<tr>
<td>Phosphate rock</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>MAP</td>
<td>41</td>
<td>59</td>
</tr>
<tr>
<td>Potash</td>
<td>27</td>
<td>27</td>
</tr>
</tbody>
</table>

a. Material basis.

**Table 3. Main Fertilizer Producing Countries in the FSU (1998)**

<table>
<thead>
<tr>
<th>Product</th>
<th>Russia</th>
<th>Ukraine</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>(% of world total) -</td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>54</td>
<td>27</td>
</tr>
<tr>
<td>Urea</td>
<td>44</td>
<td>35</td>
</tr>
<tr>
<td>AN/CAN</td>
<td>54</td>
<td>17</td>
</tr>
<tr>
<td>Phosphate rock</td>
<td>87</td>
<td>0</td>
</tr>
<tr>
<td>MAP</td>
<td>59</td>
<td>12</td>
</tr>
<tr>
<td>Potash</td>
<td>50</td>
<td>0</td>
</tr>
</tbody>
</table>

a. Material basis.

Uzbekistan (16% of the ammonium nitrate/calcium ammonium nitrate) were significant fertili-
zer producers in the FSU.

Phosphate rock production has declined substantially from its 1988 level. However, the decline appears to have reached bottom, and FSU phosphate rock production increased from 10.2 mt product in 1996 to 11.0 mt in 1997. Exports increased from 2.2 mt product in 1996 to 2.7 mt in 1997 and 3.1 mt in 1998. The increases are of Kola rock, and production from the Kola mines is expected to continue to increase. Production at Karatau fell to an estimated 1.0 mt in 1997 compared with 1.5 mt in 1996 and 14.3 mt in 1988. The Karatau mine did not operate in 1998, resulting in a decline in total FSU pro-
duction; deliveries from Karatau were taken from stock.

- **Processed Phosphates**—In 1992 FSU exports of mono-
ammonium phosphate (MAP) were substantial, often at a very low price. Since then ex-
ports have decreased due to the increasing cost of energy and transport. In addition to high energy and transport costs, producers also have to cope with the costly transport of phosphate rock and sulfur. Several plants are idle. Annual MAP exports today amount to about 1.0 mt P2O5. In addition, Russian exported 0.40 mt P2O5 as diammonium phosphate (DAP) in 1998 compared with 0.35 mt P2O5 in 1997. This increase is perhaps indicative; there could be an increase in Russian MAP and compound (NPK) fertilizer production and exports in future years, espe-
cially in view of the growing market for compound fertili-
izers in China.

Total Russian production of all phosphate fertilizers reached 1.7 mt P2O5 in 1998.
compared with 1.8 and 1.6 mt, respectively, in the two previous years. There is some phosphate fertilizer production in Ukraine, but in the rest of the CIS, production of phosphate fertilizers is very small due to the lack of domestic phosphate rock reserves and low domestic demand.

**Potash**—The FSU has two main potash-producing regions, Belaruskali in Belarus and Sylvinit and Uralkali in the Russian Urals. The major export port is Ventspils in Latvia.

Production has fallen sharply from its 1989 levels due to the decline in domestic markets and exports to other countries of the FSU. The decline in production reached bottom in 1994. In 1997, the production in Belarus and Russia increased by 20% and 30%, respectively, and increased again (+6% and +2%, respectively) in 1998. In 1998 the FSU accounted for 27% of world potash production as compared with 35% in 1989.

**Fertilizer Consumption**

In 1997 the FSU accounted for 3.1% of world fertilizer consumption, whereas in 1989 it accounted for 17%. Between 1989 and 1994, fertilizer consumption in the FSU fell from 24.5 to 4.4 mt nutrients, a decline of over 80%. In 1995 consumption stabilized, and there was some increase in 1996. Consumption increased by 4% in 1997, but declined again in 1998. Consumption data for 1997 are given in Table 4.

In 1997 the Russian Federation accounted for 33% of the region’s fertilizer nutrient consumption. Uzbekistan for 21%, Belarus for 18%, and Ukraine for 12%. These four states accounted for 84% of the FSU total in 1997. The Baltic states accounted for 4% of the total in the same year.

### Table 4. Fertilizer Consumption in the FSU (1997)

<table>
<thead>
<tr>
<th>Country</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>Total (’000 mt nutrient)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia</td>
<td>980</td>
<td>320</td>
<td>280</td>
<td>1,580</td>
</tr>
<tr>
<td>Ukraine</td>
<td>413</td>
<td>104</td>
<td>45</td>
<td>562</td>
</tr>
<tr>
<td>Belarus</td>
<td>280</td>
<td>100</td>
<td>475</td>
<td>855</td>
</tr>
<tr>
<td>Uzbekistan a</td>
<td>670</td>
<td>371</td>
<td>75</td>
<td>1,116</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>67</td>
<td>54</td>
<td>6</td>
<td>127</td>
</tr>
<tr>
<td>Baltic States</td>
<td>121</td>
<td>27</td>
<td>49</td>
<td>197</td>
</tr>
<tr>
<td>Others</td>
<td>305</td>
<td>98</td>
<td>41</td>
<td>444</td>
</tr>
<tr>
<td>Total listed</td>
<td>2,836</td>
<td>1,074</td>
<td>971</td>
<td>4,881</td>
</tr>
<tr>
<td>Total 1989</td>
<td>9,920</td>
<td>8,180</td>
<td>6,380</td>
<td>24,480</td>
</tr>
</tbody>
</table>


Source: FAO/IFA.

In Russia domestic fertilizer demand is very low due to the insolvency of agriculture. Fertilizer consumption fell in 1997 and again in 1998. The new government is promising more state support to agriculture. The financial resources are probably insufficient to realize the intentions, but the measures are likely to be implemented in part. The devaluation of the ruble makes agricultural exports much more expensive and hence encourages domestic agriculture. There is still no decision concerning land privatization.

In Belarus and Uzbekistan the centrally planned system is still in place, with heavy state support and direction of agriculture. The President of Belarus is a former head of a collective farm and pays particular attention to the agricultural sector.

In Ukraine the economy is stabilizing. In regard to agriculture, the government is taking energetic financial measures to increase the use of inputs. A package of measures aimed at liberalizing and revitalizing the agricultural sector has been implemented. They include a commitment to cut state grain procurement, an important step towards bringing market incentives to farmers. The state enterprise, which to date has controlled the storage and distribution of grain, is due to be privatized. A recent law permits private land ownership with some restrictions. The Ministry is optimistic about future fertilizer consumption. With some of the richest soils in the world, Ukraine was the world’s largest cereal exporter in the 1930s; thus, there is considerable agricultural potential.

**Upstream and Downstream Sectors**

During the 1970s, the Selkoz-Chimie system was established in the Soviet Union with transport and storage facilities. This system dealt with the planned distribution of fertilizers among the kolkhozes and sovkhozes, including contract spreading of fertilizer. The system was inefficient in respect to transportation, storage, and use. With the change to a market economy, farmers lack financial means. Expenditures on seed, fuel, electricity, salaries, and machinery tend to take precedence over fertilizer purchases.

Some of the more prosperous fertilizer plants have established their own distribution centers at the oblast or regional level. The
pace of development of private sector marketing channels in agriculture remains slow, and for the time being farms have little option but to deliver the bulk of their produce to state agencies or their direct successors, especially in view of the control still wielded by the latter with respect to farm inputs, transport, and storage facilities. Under the Soviet system farms did not have storage facilities. Processors have ample capacity, and competition with them is difficult for farmers. The situation is worst in the grain-producing regions.

The depreciation of the ruble has made food imports much more expensive in ruble terms, which should benefit domestic agriculture.

**The Baltic States**

The GDPs of the Baltic states in 1999 are expected to reach 60% to 80% of their 1989 level with Estonia faring the best. Table 5 gives population, land, and fertilizer consumption data for the Baltic states.

Fertilizer consumption in the Baltic states is progressing steadily, but they represent only 5% of total FSU consumption. In 1998 LIFOSA in Lithuania changed its production to DAP, after retrofitting its production units. With the availability of phosphate from the nearby Kola peninsula, nitrogen from Achema’s plant, low-cost sulfur, and good port facilities, the company’s output of DAP has increased significantly.

**Central and Eastern Europe**

**Structure**

The total population of the CEE region is 122 million, of which 38 million are in Poland and 23 million are in Romania (Table 6). For comparison, the total population of the European Union (EU) is 370 million and the FSU 293 million. The proportion of the economically active population engaged in agriculture ranges from 27% in Poland to 4% in the Czech Republic, compared with an average of 8% in the EU.

In 1999 it is expected that the GDP in Poland will be 120% of that of 1989; those of Slovakia, Hungary, and the Czech Republic will be at or near the 1989 levels—a much better performance than that of the FSU. However, the 1999 GDPs of Bulgaria and Romania will be around 70% of their 1989 levels.

**Fertilizer Production and Exports**

**Nitrogen**—Central Europe has been a significant net exporter of AN and urea but has less than 1% of the world’s natural gas reserves (Tables 7 and 8).

In 1997 urea exports from the region declined by 30% compared with 1996, due to a 55% decrease in exports from Romania. There was a further large decline in 1998 with exports from Romania falling to a negligible level. In Romania much of the capacity is not operating while awaiting the sale of product.

### Table 5. Some Data for the Baltic States

| Country  | Population (million) | Agricultural Area (million ha) | Fertilizer Rate (kg/ha) 
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Estonia</td>
<td>1.5</td>
<td>1.4</td>
<td>30</td>
</tr>
<tr>
<td>Latvia</td>
<td>2.5</td>
<td>2.5</td>
<td>37</td>
</tr>
<tr>
<td>Lithuania</td>
<td>3.7</td>
<td>3.5</td>
<td>25</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7.7</strong></td>
<td><strong>7.4</strong></td>
<td></td>
</tr>
</tbody>
</table>

a. N + P₂O₅ + K₂O.

### Table 6. Data for Some Countries of CEE

<table>
<thead>
<tr>
<th>Country</th>
<th>Population (million)</th>
<th>Agricultural Area (million ha)</th>
<th>Fertilizer Rate (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulgaria</td>
<td>8</td>
<td>6</td>
<td>38</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>10</td>
<td>4</td>
<td>77</td>
</tr>
<tr>
<td>Hungary</td>
<td>10</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>Poland</td>
<td>38</td>
<td>19</td>
<td>88</td>
</tr>
<tr>
<td>Romania</td>
<td>23</td>
<td>15</td>
<td>31</td>
</tr>
<tr>
<td>Slovakia</td>
<td>5</td>
<td>2</td>
<td>49</td>
</tr>
<tr>
<td>Others</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total CEE</strong></td>
<td>122</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total EU</strong></td>
<td>370</td>
<td>138</td>
<td>130</td>
</tr>
</tbody>
</table>

a. N + P₂O₅ + K₂O.
b. For comparison: France 190 kg/ha, Germany 176 kg/ha, and United States 138 kg/ha.  
c. Albania, Bosnia-Herzegovina, Croatia, Macedonia, Slovenia, and Yugoslavia.
Based on fuel oil. In the Slovak public, the ammonia plants are from Russia. In the Czech Republic, the most fertilizer plants in the region are located in Slovakia. Former Yugoslavia have significant sulfur resources, now dispersed and have weak bargaining power; they do not have the bargaining power of the former centrally controlled enterprises. The decline in Russian demand for imported agricultural products has exacerbated the situation.
Today the countries of CEE and the FSU account for only 6% of world fertilizer consumption compared with 16% in 1989. In both regions, it is unlikely that the 1988 peak levels of fertilizer consumption will be reached again within the foreseeable future. It should be possible to regain former levels of agricultural production with less fertilizer as market disciplines reduce waste and increase the efficiency of use. Under the centrally planned system, there were large fertilizer losses in both the distribution system and in application, especially in the FSU.

The recovery in fertilizer consumption is much slower than was expected and hoped for. This is no doubt due largely to the problems of farm ownership and the deficiencies of the downstream agricultural produce marketing sectors. Credit for the purchase of inputs tends to be expensive; moreover, many farmers still do not have title to their land and thus lack an important form of collateral for credit.

Fertilizer production also has fallen but less so than consumption, providing a larger surplus available for the export market. The Russian Federation is well endowed with all of the natural resources required for the production of fertilizers but all the other countries of the regions lack one or more, some of them all, the necessary raw materials.

### Table 9. Fertilizer Consumption for CEE Countries (1995-97)

<table>
<thead>
<tr>
<th>Country</th>
<th>1995 (000 mt N + P₂O₅ + K₂O)</th>
<th>1996 (000 mt N + P₂O₅ + K₂O)</th>
<th>1997 (000 mt N + P₂O₅ + K₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulgaria</td>
<td>154</td>
<td>165</td>
<td>171</td>
</tr>
<tr>
<td>Croatia</td>
<td>81</td>
<td>198</td>
<td>243</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>349</td>
<td>346</td>
<td>314</td>
</tr>
<tr>
<td>Hungary</td>
<td>342</td>
<td>454</td>
<td>430</td>
</tr>
<tr>
<td>Poland</td>
<td>1,512</td>
<td>1,575</td>
<td>1,603</td>
</tr>
<tr>
<td>Romania</td>
<td>363</td>
<td>422</td>
<td>315</td>
</tr>
<tr>
<td>Slovenia</td>
<td>74</td>
<td>74</td>
<td>75</td>
</tr>
<tr>
<td>Slovak Republic</td>
<td>104</td>
<td>119</td>
<td>107</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>163</td>
<td>214</td>
<td>234</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,142</strong></td>
<td><strong>3,567</strong></td>
<td><strong>3,492</strong></td>
</tr>
</tbody>
</table>

Conclusion

Today the countries of CEE and the FSU account for only 6% of world fertilizer consumption compared with 16% in 1989. In both regions, it is unlikely that the 1988 peak levels of fertilizer consumption will be reached again within the foreseeable future. It should be possible to regain former levels of agricultural production with less fertilizer as market disciplines reduce waste and increase the efficiency of use. Under the centrally planned system, there were large fertilizer losses in both the distribution system and in application, especially in the FSU.

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Fertilizer production also has fallen but less so than consumption, providing a larger surplus available for the export market. The Russian Federation is well endowed with all of the natural resources required for the production of fertilizers but all the other countries of the regions lack one or more, some of them all, the necessary raw materials.
The Fertilizer Industry in the Russian Federation—Economic and Environmental Performance

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Centre for Preparation and Implementation of International Projects on Technical Assistance, Environmental Management Project for the Russian Federation, Moscow

Introduction

The Russian chemical industry consists of four large blocks: (1) chemical, (2) petrochemical, (3) agrochemical, and (4) biotechnological. It includes more than 5,800 enterprises of which 600 are large and medium size. The chemical industry in Russia accounts for approximately 6.5% of economic output and occupies fifth place in the whole Russian industry. The chemical industry was strong in the Former Soviet Union. After collapse of the Soviet Union, the output of the chemical industry decreased significantly and, in general, this industry sector has experienced serious economic problems. In 1994 the output of the chemical industry was only 42.5% of that in 1989. Indices of the production output of the chemical industry during 1990-98 are given in Table 1.

The decrease in 1994 and general decrease of chemical industry output during the last decade was greater than in other industrial sectors. For example, the chemical industry’s share of Russia’s GDP dropped from 6.8% in 1990 to 5.9% in 1995, well below the average for economically developed countries. In 1995 after a decade of declining output, some stabilization occurred in the Russian chemical industry due to the increase of exports of chemical products. This factor has played a stabilizing role in the chemical industry. Nevertheless, the volume of exported chemicals continues to decrease because of lower demand. Further, the domestic market has not been fully developed.

Following the collapse of the Soviet Union, the demand for chemicals in Russia has fallen, and the output of some chemical products has been significantly reduced. Formerly, trading of chemicals took place in the entire Soviet Union but now is limited to the Russian Federation. On the other hand, the export of chemicals from Russia has increased. Based on this situation, experts predict that the prospect for growth of this industrial sector in the near future is not good.

Today, the Russian chemical industry as a whole accounts for about 2% of world chemical output, which is less than one-tenth of that of the United States. It is only one-half to three-quarters of the output of such countries as France, the United Kingdom, and Italy, which all have much smaller populations. The Basic Organic and Inorganic Chemicals Sector is actually smaller than some of the larger international chemical companies, and it accounts for about one-third of the total output of the Russian chemical industry.

The decline has not been uniform among subsectors of the industry. Fertilizers and organic chemicals, which are the largest subsectors, have been declining at a rate less than average, and all of the others except inorganic

<table>
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<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>97.8</td>
<td>93.7</td>
<td>78.3</td>
<td>78.5</td>
<td>75.5</td>
<td>107.6</td>
<td>92.9</td>
<td>102.2</td>
<td>92.5</td>
</tr>
</tbody>
</table>

% compared with previous year

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>97.8</td>
<td>91.6</td>
<td>71.8</td>
<td>56.3</td>
<td>42.5</td>
<td>45.8</td>
<td>42.5</td>
<td>43.4</td>
<td>40.2</td>
</tr>
</tbody>
</table>

% compared with 1989

Table 1. Indices of the Production Output of the Russian Chemical Industry
compounds have been declining at rates that are more than the average. In 1996 as in 1991, fertilizers were the dominant product of the sector and accounted for 47% of production (40% in 1990).

This paper discusses the current state, both the economic and environmental performance, of the fertilizer industry in the Russian Federation. The discussions incorporate the results of the Sectoral Environmental Action Plan for Basic Organic and Inorganic Chemicals sector developed by the Centre for Preparation and Implementation of International Projects on Technical Assistance in cooperation with Arthur D. Little International, Inc., an international consulting company. The project is under the framework of the Environmental Management Project for the Russian Federation financed by the World Bank.

**Economic Performance of the Fertilizer Subsector in the Russian Federation**

**General Overview**

According to research conducted in 1997 by the Russian bank, Rossiysky Credit, production of chemical fertilizers is one of the most profitable and financially sound sectors of the Russian economy. There are 54 enterprises in the Russian Federation producing fertilizers. The research included thorough analyses of 36 of these enterprises. Most enterprises are located in European Russia, i.e., west of the Ural Mountains. Only one large enterprise is located east of the Urals in Kemerovo. Table 2 contains a list of the main chemical fertilizer enterprises and also indicates their location and the main products.

Table 3 shows the production of chemical fertilizers in the Russian Federation for the period 1970-98. Estimates of the Russian Ministry of Economics for year 1999 are also included. Production tonnages of different types of chemical fertilizers from 1991 to 1997 are given in Table 4.

In 1990 the chemical fertilizer sector capacity was 20.8 million tons, and sector output was 15.98 million tons, which included 7.19 million tons of nitrogen fertilizers, 4.94 million tons of phosphate fertilizers, and 3.85 million tons of potassium fertilizers. In 1998 this sector had the capacity to produce 19.7 million tons of chemical fertilizers, including 8.2 million tons of nitrogen fertilizers, 4.9 million tons of phosphate fertilizers, and 6.6 million tons of potassium fertilizers. Production of chemical fertilizer decreased by a factor of 1.8 during 1990-97. At the same time, production of nitrogen fertilizer declined by a factor of 1.8, and phosphate fertilizer production decreased by a factor of 2.7. The share of potassium fertilizer production increased 35.8% (24.1% in 1990), and the share of phosphate fertilizer production decreased to 18.9% (30.9% in 1990). Considerable changes in the types of products also occurred. Production of double superphosphate, complex liquid fertilizers, chloride-free potassium fertilizers, and high-quality phosphate fertilizers was essentially discontinued.

After the general decline of overall industrial production in Russia during the period, 1991-94, the chemical industry was recognized as one of the few Russian industries with increased production. Production rose by 20% in 1995. In 1995 total Russian production of ammonia and nitrogen fertilizers was 9.66 million tons and 4.88 million tons, respectively. In 1996 production of nitrogen fertilizers increased, whereas the production of ammonia decreased. In 1997 Russian chemical companies had the capacity to produce up to 15 million tons of ammonia and 8.8 million tons of nitrogen fertilizers.

Of the entire range of chemical fertilizers produced in Russia, the largest share is nitrogen fertilizers. According to the study referred to earlier, 13% of the world’s supply of nitrogen fertilizers is produced in Russia. Among nitrogen fertilizers, there is a major demand for urea, which comprises 40% of Russia’s total nitrogen fertilizer production. There is also high demand for ammonium nitrate, which makes up 35% of Russia’s production. Aqua ammonia solution is another product that can be produced according to the market demand.

Currently, about 20 chemical companies in Russia are producing about 80% of the total volume of nitrogen fertilizers and 92.4% of ammonia. The balance is produced by companies in the petrochemical and metallurgical industries. However, 10 large companies lead the production with their total share of 70% for nitrogen fertilizers and 85% for ammonia. These are Akron (Novgorod), ToliattiAzot (Toliatti), Azot (Novomoskovsk), Azot (Kemerovo), Nevinnomyssky Azot (Nevinnomyssk), Azot (Cherepovets), Kuybyshhevazot (Toliatti), Minudobrenia (Rossosh), Azot (Bereznyaki), and Dorogobuzh (Smolensk). Most of these companies are profitable and growing. At present, their production facilities are used to a much larger extent than in the Russian chemical industry as a whole. The average actual production is 64% of the capacity for the production of ammonia and 55% of the capacity for the production of nitrogen fertilizers. This should be compared with 35% in other chemical production facilities. Another noteworthy feature of this nitrogen fertilizer
<table>
<thead>
<tr>
<th>No.</th>
<th>Enterprise Name</th>
<th>City, Region</th>
<th>Geographical Region</th>
<th>Main Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>JSC “Akron”</td>
<td>Novgorod, Novgorod region</td>
<td>North-West Russia</td>
<td>Ammonia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lermontov, Stavropol region</td>
<td>Southern Russia</td>
<td>Chemical fertilizers</td>
</tr>
<tr>
<td>2.</td>
<td>“Almaz” of the</td>
<td>Cherepovets, Vologda region</td>
<td>Upper Volga</td>
<td>Ammophos</td>
</tr>
<tr>
<td></td>
<td>“Atomredmetzoloto” concern</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>JSC “Ammophos”</td>
<td>Kirovsk, Murmansk region</td>
<td>Northern Russia</td>
<td>Phosphate fertilizers</td>
</tr>
<tr>
<td>4.</td>
<td>JSC “Apatit”</td>
<td>Bereznuki, Perm region</td>
<td>Ural</td>
<td>Sodium nitrite</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ammonium nitrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Potassium nitrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>5.</td>
<td>JSC “Azot”</td>
<td>Belorechnsk, Krasnodar region</td>
<td>Southern Russia</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>6.</td>
<td>Bryansk Phosphate Fertilizer Plant</td>
<td>Bryansk, Bryansk region</td>
<td>Central Russia</td>
<td>Phosphate fertilizers</td>
</tr>
<tr>
<td>7.</td>
<td>JSC “Chelyabinsky plant of organic glass”</td>
<td>Chelyabinsk, Chelyabinsk region</td>
<td>Ural</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>8.</td>
<td>JSC Chemical Plant “Irgiz”</td>
<td>Balakovo-18, Saratov region</td>
<td>Middle Volga</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>9.</td>
<td>Cherepovets PO “Azot”</td>
<td>Cherepovets, Vologda region</td>
<td>Upper Volga</td>
<td>Ammonia</td>
</tr>
<tr>
<td>10.</td>
<td>JSC “Dogoz”</td>
<td>Kyzyl-yurt, Dagestan Republic</td>
<td>Southern Russia</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>11.</td>
<td>JSC “Dagos”</td>
<td>Dogobuzh, Smolensk region</td>
<td>Central Russia</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>12.</td>
<td>JSC “Efremov Chemical Plant”</td>
<td>Efremov, Tula region</td>
<td>Central Russia</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>13.</td>
<td>JSC “Fosforit”</td>
<td>Kingisepp, Leningrad region</td>
<td>North-West Russia</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>14.</td>
<td>Kemerovo JSC “Azot”</td>
<td>Kemerovo, Kemerovo region</td>
<td>Western Siberia</td>
<td>Ammonia</td>
</tr>
<tr>
<td>15.</td>
<td>JSC “Korund”</td>
<td>Dzerzhinsk, Nizhni Novgorod region</td>
<td>Upper Volga</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>16.</td>
<td>JSC “Kuibyshevazot”</td>
<td>Togliatti, Samara region</td>
<td>Middle Volga</td>
<td>Ammonia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ammonium sulfate and nitrate</td>
</tr>
<tr>
<td>17.</td>
<td>JSC “Nevinnomyssky Azot” (JV “Foreign Tradeinvest”)</td>
<td>Nevinnomyssk-7, Stavropol region</td>
<td>South Russia</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>18.</td>
<td>JSC “Sarmat”</td>
<td>Rossosh-1, Voronezh region</td>
<td>Central Russia</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>19.</td>
<td>JSC “Sarmat”</td>
<td>Perm, Perm region</td>
<td>Urals</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>20.</td>
<td>JSC “Sarmat”</td>
<td>Nevinomnyssk-7, Stavropol region</td>
<td>South Russia</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>21.</td>
<td>JSC “Sarmat”</td>
<td>Nevinnomyssk-7, Stavropol region</td>
<td>South Russia</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>22.</td>
<td>Novomendeleevsky</td>
<td>Mendeleevsk, Tatarstan Republic</td>
<td>Middle Volga</td>
<td>Nitrogen fertilizers</td>
</tr>
</tbody>
</table>

(Continued)
### Table 2. Principal Producers of Chemical Fertilizers in Russia (Continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Enterprise Name</th>
<th>City, Region</th>
<th>Geographical Region</th>
<th>Main Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.</td>
<td>Novomoskovskaya AK “Azot” Chemical Plant</td>
<td>Novomoskovsk, Tula region</td>
<td>Central Russia</td>
<td>Ammonia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Phosphate fertilizers</td>
</tr>
<tr>
<td>24.</td>
<td>JSC “Phosphate Fertilizers”</td>
<td>Lopatinsky, Moscov region</td>
<td>Central Russia</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Phosphate fertilizers</td>
</tr>
<tr>
<td>25.</td>
<td>JSC “Phosphorus”</td>
<td>Togliatti, Samara region</td>
<td>Middle Volga</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Phosphate fertilizers</td>
</tr>
<tr>
<td>26.</td>
<td>JSC “Silvinit”</td>
<td>Solikamsk, Perm region</td>
<td>Ural</td>
<td>Potassium chloride</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Potassium fertilizers</td>
</tr>
<tr>
<td>27.</td>
<td>JSC “Togliatti Azot”</td>
<td>Togliatti, Samara region</td>
<td>Middle Volga</td>
<td>Ammonia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nitrogen fertilizers, urea</td>
</tr>
<tr>
<td>28.</td>
<td>PO “Transammiak”</td>
<td>Togliatti, Samara region</td>
<td>Middle Volga</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>29.</td>
<td>JSC “Uralkaliy”</td>
<td>Berezniki, Perm region</td>
<td>Ural</td>
<td>Potassium fertilizers</td>
</tr>
<tr>
<td>30.</td>
<td>JSC “Uvarovsky Chemical Plant”</td>
<td>Uvarovo-5, Tambov region</td>
<td>Central Russia</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Phosphate fertilizers</td>
</tr>
<tr>
<td>31.</td>
<td>JSC “Verhneakmsky phosphorudnik”</td>
<td>p.Rudnichny, Kirov region</td>
<td>Northern Russia</td>
<td>Phosphate fertilizers</td>
</tr>
<tr>
<td>32.</td>
<td>JSC “Voskreensk Mineral Fertilizers”</td>
<td>Voskresensk, Moscow region</td>
<td>Central Russia</td>
<td>Phosphate fertilizers</td>
</tr>
<tr>
<td>33.</td>
<td>Kirovo-Chepetsk Chemical Combine</td>
<td>Kirow region</td>
<td>Northern Russia</td>
<td>Chemical fertilizers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34.</td>
<td>JSC “Organic glass”</td>
<td>Dzerzhinsk, Novgorod region</td>
<td>Upper Volga</td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>35.</td>
<td>JSC “Schlokinazot”</td>
<td>Schlokin, Tula region</td>
<td>Central Russia</td>
<td>Ammonia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nitrogen fertilizers</td>
</tr>
<tr>
<td>36.</td>
<td>JSC “Caprolactam”</td>
<td>Dzerzhinsk, Novgorod region</td>
<td>Upper Volga</td>
<td>Nitrogen fertilizers</td>
</tr>
</tbody>
</table>

### Table 3. Production of Chemical Fertilizers in the Russian Federation

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>6,270</td>
<td>11,772</td>
<td>15,979</td>
<td>15,042</td>
<td>12,300</td>
<td>9,917</td>
<td>8,266</td>
<td>9,639</td>
<td>9,076</td>
<td>9,532</td>
<td>9,346</td>
<td>9,800</td>
</tr>
</tbody>
</table>

### Table 4. Production of Different Types of Chemical Fertilizers in the Russian Federation During 1991-97

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>6,680</td>
<td>5,820</td>
<td>4,780</td>
<td>4,050</td>
<td>4,880</td>
<td>469</td>
<td>4,290</td>
</tr>
<tr>
<td>Potassium</td>
<td>4,270</td>
<td>3,470</td>
<td>2,630</td>
<td>2,500</td>
<td>2,830</td>
<td>2,670</td>
<td>3,440</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>4,090</td>
<td>3,020</td>
<td>2,510</td>
<td>1,720</td>
<td>1,930</td>
<td>1,970</td>
<td>1,800</td>
</tr>
</tbody>
</table>
subsector is that none of these companies owe debts to the Russian Federal Government, which is a rare exception among most large Russian manufacturers.

**Raw Materials**

Russia's raw materials base for the three primary fertilizer nutrients is good. Phosphate rock supply is represented by 41 explored deposits with remaining balances of 900 million tons of P₂O₅. Currently only 11 of them are being exploited. Total deposits of potassium fertilizers are estimated at 18.8 billion tons when calculated to K₂O. This provides a long-term supply for the enterprises engaged in exploiting the deposits. The main raw material for production of nitrogen fertilizers is natural gas. Consumption of natural gas for nitrogen fertilizer production is about 2%-3% of the total annual production of natural gas.

Unfortunately, there were very few investments in the development of phosphate rock deposits during previous years. Apatite deposits being correctly mined will soon be depleted, and new mines have not been prepared for exploitation. In addition, most deposits are located in the northern part of Russia, far away from main-producing enterprises, and high transport costs will result in decrease of price competitiveness of Russian phosphate fertilizers. Potassium fertilizer raw material supply has been seriously affected by the earthquake in 1995. Large investments are needed to rebuild the industry.

**Domestic Consumption, Exports, and Imports**

Domestic fertilizer consumption has collapsed since the end of the Soviet period. However, the fertilizer subsector is one of the healthiest subsectors in the Russian chemical industry because this subsector has been able to offset the decline in domestic consumption with exports. Table 5 lists some of the key products of the fertilizer subsector, their 1997 consumption (based on mid-year projections), and the percentage change from 1994.

Growth in consumption occurred for nitrogen and phosphate fertilizers, but the consumption of potassium fertilizers decreased by 30%. Although domestic demand for some types of fertilizers has increased over the past few years, the increases have not been sufficient to make up for the reductions in consumption since the end of the Soviet period. In several cases, large growth could take place in the Russian domestic market, either through the modification of current government policies or through improved conditions for chemical consumers.

Domestic consumption of fertilizers in Russia is but a fraction of what it once was. Application of chemical fertilizers is reported to have fallen from 80 kg/ha in the mid-1980s to 10 kg/ha in the mid-1990s. The current levels of application are insufficient to maintain soil fertility, and for this (and other) reasons agricultural output per hectare is much lower than it could be.

Reform of the Russian agricultural sector has been extremely slow. Most farms are still collectivized. The farms are overstaffed and burdened with social obligations. A federal law providing for the mechanism to transfer land to private ownership has yet to be enacted due to political opposition. As a result, farms are short of cash for necessities like fertilizers and lack the ability to use land as collateral for obtaining loans to buy supplies. Thus, while the domestic market potential for mineral fertilizers is substantial, it depends on the reforms coming to the agricultural sector that will allow farmers to manage their land properly. The relatively few farms that have been privatized have lead to an increase in domestic demand for complex fertilizers.

Fertilizer producers could also improve domestic sales by changing their pricing strategies. Domestic prices for nitrogenous fertilizers are sometimes set higher than international ones, which undermines the ability of Russian consumers to buy domestically produced fertilizers and restricts opportunities for

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### Table 5. Russian Domestic Consumption of Selected Basic Organic and Inorganic Chemicals in 1997 and Percentage Change From 1994

<table>
<thead>
<tr>
<th>Compound</th>
<th>1997 Consumption ('000 tons)</th>
<th>Percentage Change From 1994 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>6,316</td>
<td>16</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>780</td>
<td>13</td>
</tr>
<tr>
<td>Ammonium phosphate</td>
<td>332</td>
<td>16</td>
</tr>
<tr>
<td>Urea</td>
<td>276</td>
<td>-1.8</td>
</tr>
<tr>
<td>Nitric acid</td>
<td>4,823</td>
<td>13</td>
</tr>
<tr>
<td>Potassium chloride</td>
<td>326</td>
<td>-30</td>
</tr>
</tbody>
</table>

Note: 1997 consumption figures are based on mid-year projections.
domestic market growth. Fertilizer producers could use the strategy of the United Energy System (UES), the Russian electricity monopoly, as an example and provide discounts for cash payments as a means of reducing prices and at the same time eliminating barter transactions.

The relative stability of Russian companies working in the nitrogen industry is the result of continuous demand for these products in both local and international markets. In Russia, the Agro-Industrial Complex (AIC), supported and partially funded by the Russian government, is a large user of fertilizers. However, despite the recent increase in the sales of fertilizers to the AIC, fertilizer consumption by Russia’s agricultural sector remains very low: almost 6.8 times less than in 1991. In 1991 the amount of chemical fertilizers sold inside the country equaled 59% of total production of all types of fertilizers. In 1997 it equaled only about 26%. According to the Russian Ministry of Economy, during the spring of 1999 the supply of agricultural products is also insufficient. Only two regions among 89 in the Russian Federation were supplied by more than one-half of the necessary amount. The main reason for this is the inability of agricultural companies to pay for fertilizers.

Consequently, exports provide the most important sales volume, although according to manufacturers of fertilizers, they want to expand their domestic market share because the prices of these products in Russia are higher than export prices. At present, Russia exports over 70% of its urea production, about 50% of ammonium nitrate, and 40% of ammonia. As compared with 1991, exports of nitrogen fertilizers have increased by 70%. The largest importers of Russian fertilizers are China and India. Fertilizers are also exported to South East Asia, Europe, and South America. In 1998 China discontinued importing nitrogen fertilizers from Russia, and as a result total exports of nitrogen fertilizers have recently declined.

Although the nitrogen fertilizer subsector has a much larger role in the global chemical business—ammonia and urea accounting for about 15% of world production as recently as 1996—even this subsector is threatened by the growing gap between the production technologies they employ and modern international technologies at a time when their advantage in raw material costs is shrinking if not disappearing.

Fertilizer is a primary export product for Russia. Net exports amount to over 3 billion dollars per year and are largely responsible for chemical products accounting for 10% of Russia’s export earnings. The tonnage and value of the main Russian fertilizer exports and imports are shown in Figures 1 and 2. More importantly, imports of the fertilizers in which Russia trades are negligible.

Over the last 3 years, the structure of exports has changed in favor of fertilizer manufacturers. The share of this subsector in exports of chemical products has grown from 62% (1994) to 89% (1996). Over the last 3 years the share of fertilizers in imports has dropped by one-half. This situation results from these factors:

- Continuing decline in the production of consuming sectors.
- Lack of circulating assets and insolvency of many enterprises.
- Growth of prices for imported products.
- Problems relating to cargoes crossing the country’s border.

In any case, imports of fertilizers into Russia are insignificant compared with exports and domestic production.

The trends in exports between 1994 and 1997 for the fertilizer subsector are as follows:

- Exports of the primary exporting subsector of the chemical products.

**Figure 1. Tonnage of 1996 Russian Imports and Exports of the Most Significant Chemical Products.**
industry remain stable. Some 75%-80% of the physical volume of fertilizers manufactured in Russia is exported. According to various estimates, Russia’s deliveries of ammonia and urea accounted for 30% of the world trade in 1996. The main negative factors influencing Russian chemical fertilizer exports between 1990 and 1995 were high inflation and high production and transportation costs. The other negative factor that influenced export dynamics was declining world prices for chemicals. Prices for such chemical products as ammonium nitrate decreased by 15%. The critical factor in this process was increasing prices for energy and gas, which made production unprofitable.

- Exports of ammonium phosphate (in tons) have declined over the past 3 years, but since no significant shifts in demand for phosphate fertilizers on foreign markets are expected for the near future, Russia will likely retain its export position on this item. Exports of potassium and nitrogenous fertilizers appear to have leveled off between 1994 and 1996. In early 1997, China, the main importer of Russian urea, sharply reduced purchases due to the installation of domestic capacity.

### International Market for Fertilizers

An analysis of the general financial performance of the fertilizer products in various parts of the world and a review of the historic and projected (through 2000) worldwide market for several selected fertilizer products were carried out to help assess the potential export market for products of the chemical fertilizer subsector in the Russian Federation. The results of this work are summarized below.

### Chemical Industry Performance

The financial performance of the worldwide chemical industry in the past few years has been generally flat. Sales and earnings of the U.S. chemical industry were reduced by 1% and 13%, respectively, from 1995 to 1996 and the aggregate profitability of the top 30 companies declined from 9.7% in 1995 to 8.5% in 1996. The profit margin of industrial chemicals declined from 10.1% in 1995 to 7.2% in 1996. The profit margin of fertilizers was reduced from 7% in 1995 to 5.8% in 1996. The Return on Invested Capital (ROIC) for the U.S. chemical industry as a whole in 1996 was respectable at about 10.7% with some segments having strong returns (e.g., pharmaceuticals at 20%, fertilizers at 15.5%, diversified chemicals at 16.3%).

After two good years, the European chemical industry slowed in 1996. However, production figures showed mixed patterns. Germany and Spain, two major producers, experienced a decline in production. The chemical industries in Hungary, Poland, and Slovakia showed growth in overall sales. The profit margins of 19 major European chemical companies were in the aggregate at a level of 5.8% in 1996, which is lower than the 8.5% posted by the top 30 U.S. chemical companies.

The sectoral breakdown of European chemical sales shows that fertilizers account for only 2% of output. General conclusions that can be reached as a result of this information are that the worldwide chemical industry is much more financially strong than the Russian chemical industry, and the softening of sales and earnings will make the main chemical companies aware of any attempts to take over parts of this market.
of their markets (i.e., it will make it tougher for Russia to break into new export markets).

**Analysis of Potential Export Markets**—The results of the historic and projected (through 2000) markets for the 37 chemicals selected for analysis based on their high relative production volumes and total sales values are analyzed. Using the data collected from the literature, quantitative estimates were made of the potential growth in demand and change in price (in constant dollars) for those products for which adequate information could be found. This analysis indicates that three products made by the chemical fertilizer subsector might present desirable export opportunities. Prospects for these three more attractive export candidates are discussed below.

**Phosphate Fertilizers**—Phosphate fertilizers are close to a supply/demand balance with a supply surplus estimated at 3% in 2000. In the United States, demand for ammonium phosphates is expected to grow at 2%-3%/year through 2000. The market demand in Europe is expected to increase also.

**Ammonia**—Ammonia is the second most important commodity chemical after sulfuric acid. Global demand is expected to increase by 1.8%/year until 2010. Long-term demand is expected to increase, both in the fertilizer and industrial subsectors (fertilizers for emerging countries and caprolactam for nylon fiber). The highest growth is expected in Asia and the Former Soviet Union. Supplies are currently tight due to strong demand, but new capacity is coming on stream in Latin America, which may affect this situation.

**Urea**—Urea is one of the primary intermediates used in the production of other chemical products, and it is a key fertilizer ingredient (fertilizers account for 80% of urea consumption). Demand has increased more rapidly than for many other products in recent years. Global demand is expected to rise at a rate of 1.9%/year through 2010.

**Technological Characterization of the Fertilizer Subsector**

The technological characterization of the chemical fertilizer subsector is derived from the assessment of several facilities, which were visited by “Arthur D. Little” specialists during the course of the aforementioned study. The technological characterization presented below represents opinions and judgments developed by Arthur D. Little staff as a result of facility visits, including discussions with facility personnel, facility tours, and a review of both public and private documents.

The characterization considers numerous elements relating to the design, operation, and maintenance of overall facilities and their individual production plants. Included in this review has also been the operational efficacy of the principal production technologies and their basic performance capabilities to the extent possible. The various aspects considered have been grouped into four categories for convenience of discussion:

- General facility conditions.
- Process technologies.
- Plant designs.
- Technical support capabilities.

Table 6 summarizes the overall technological characterization of the fertilizer subsector according to these four categories along with the criteria used in making these evaluations.

**Condition of Facilities**—With a few notable exceptions, facilities are generally in disrepair. Maintenance of buildings, equipment, and infrastructure (e.g., roads and pipe racks) has been minimal for several years and upkeep of grounds has been widely neglected. To some extent this is cosmetic, especially since large portions of many facilities have been shut down or idled. However, it is indicative of limited maintenance funds and, in the case of operating equipment and supporting infrastructure, it does affect production operations. The maintenance funds that are available are used for critical plant equipment, which is understandable. However, only a limited number of facilities have active preventive or predictive maintenance programs, and there is a critical shortage of spare parts in most plants. Coupled with a general decline in demand for products, this has led to the closing of the most underutilized and inefficient production units and “cannibalism” of parts to sustain other lines.

**Process Technologies**—Overall, process technologies throughout the fertilizer industry are rapidly approaching obsolescence. It is estimated that 70% or more of the technologies are aged to obsolete in terms of competitiveness and operational efficacy. As used here, “obsolete” means utilizing technology that is at least one, if not two, generations removed from current state-of-the-art and is no longer capable of cost-effectively competing in the world markets. In general, plants that have reached a state of obsolescence cannot be easily upgraded for competitive operation and usually should be considered for replacement. “Aged” refers to technologies or plants that are nearing obsolescence but can still be operated to produce products of acceptable quality but not as efficiently as modern processes. These plants are capable of “life extension” through upgrades or modernization efforts, which can extend the useful plant life for 10-15 years or perhaps longer.
Only about 20% of current technology would be considered to be in the "mainstream" of modern technology in western countries. Nevertheless, there has been some investment in new technology since the inception of privatization, and investment continues but at a slow pace. Among the several facilities visited, there has been on average about one new production plant installation and one significant upgrade of production operation per facility since 1991. This is about twice the rate of investment experienced at these same facilities during the 6 years prior to privatization (1986-91). For the most part, the highest percentage of modern technology is in the fertilizer subsector which, not surprisingly, is also a subsector deemed to be one of the strongest in terms of overall financial condition. Due to the stable growth of their production volumes and an extensive export market for their products, the fertilizer subsector of the Russian chemical industry is attractive for investments. Experts from Rossiyskiy Credit Bank report that the following six companies are considered excellent opportunities for investment: Akron (Novgorod), Minudobrenia (Perm), Nevinnomysskyy Azot (Nevinnomyyskk), Toliattiazot (Toliatti), Dorogobuzh (Smolensk), and Azot (Novomoskovsk).

### Design of Plants

Many plants are of a hybrid design, combining both Russian and foreign concepts. Frequently, this is a melding of foreign process technologies, basically "tuning" them to Russian conditions. The tuning frequently affected the design of auxiliary and ancillary systems for consistency with normal Russian infrastructure. This is an appropriate approach considering the special requirements to match Russian energy supply, weather, raw materials supply, and other specific conditions. Such adjustments are normal and usually considered "customizing." However, in some cases, this has led to inadvertent compromises that have affected efficiencies and operational efficacy. This has been further exacerbated by lack of equipment.

### Table 6. Technological Characterization of Fertilizer Subsector

<table>
<thead>
<tr>
<th>Industry Subsector</th>
<th>Fertilizers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment</td>
<td>Characterization</td>
</tr>
<tr>
<td>Technological</td>
<td></td>
</tr>
<tr>
<td>* Production Technologies</td>
<td>+</td>
</tr>
<tr>
<td>* Overall facility condition</td>
<td></td>
</tr>
<tr>
<td>* Plant designs</td>
<td></td>
</tr>
<tr>
<td>* Technical support capabilities</td>
<td>+</td>
</tr>
<tr>
<td>* Investment need for world competitiveness</td>
<td></td>
</tr>
<tr>
<td>Overall Technological Characterization</td>
<td></td>
</tr>
</tbody>
</table>

### Criteria Descriptions

<table>
<thead>
<tr>
<th>Characterization Parameter</th>
<th>Description of Ranking Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major processes that are aged to obsolete</td>
<td>+ 30%</td>
</tr>
<tr>
<td>Overall neat and well maintained</td>
<td>30 - 60%</td>
</tr>
<tr>
<td>Routine preventive maintenance</td>
<td>&gt; 60%</td>
</tr>
<tr>
<td>Shutdown plants decommissioned</td>
<td>General lack of facility upkeep</td>
</tr>
<tr>
<td>Faulty equipment</td>
<td>Maintenance programs spotty</td>
</tr>
<tr>
<td>Well-managed plant configurations</td>
<td>Shutdown plants not decommissioned</td>
</tr>
<tr>
<td>Functional, compatible M/C controls</td>
<td>General lack of facility upkeep</td>
</tr>
<tr>
<td>Significant equipment inadequacies, process/infrastructure problems, or</td>
<td>Maintenance of operating equipment</td>
</tr>
<tr>
<td>anticipated control systems</td>
<td>Shutdown plants abandoned and unready</td>
</tr>
<tr>
<td>Investment need for world competitiveness</td>
<td></td>
</tr>
<tr>
<td>Depth of technical expertise</td>
<td>&lt; 50 million USD</td>
</tr>
<tr>
<td>Strong on-site process design</td>
<td>50 - 150 million USD</td>
</tr>
<tr>
<td>Focused R&amp;D activities</td>
<td>&gt; 150 million USD</td>
</tr>
<tr>
<td>Strong on-site process design</td>
<td>&quot;Faint line&quot; technical support</td>
</tr>
<tr>
<td>On-site design is facility oriented</td>
<td>Technical support attunement</td>
</tr>
<tr>
<td>Laboratory mainly for operations</td>
<td>Design work externalized</td>
</tr>
<tr>
<td>No on-site R&amp;D capability</td>
<td></td>
</tr>
</tbody>
</table>
compatibility, related to the type of equipment selected, the materials of construction employed, and inconsistencies in the interfaces among subsystems. It is most evident in plant upgrades where efforts have been made to minimize first costs through use of local, inexperienced design houses and/or implementation with “make do” equipment.

The biggest issue, though, in terms of plant design, is energy efficiency, closely followed by recycle/reuse of byproducts and wastes. To a large extent, energy efficiency was not a principal consideration in the initial design of most facilities or other production plants. Not only has this resulted in higher operating costs as energy prices have increased but also it has made retrofit of energy conservation systems difficult because of the technology selected and the manner in which it was implemented. Most energy inefficiencies derive from higher pressures and/or temperatures than normally found in most modern chemical conversion processes and/or lack of properly integrated heat recovery for efficient steam generation.

Finally, most of the instrumentation and control systems are out of date, although functional. This is generally reflective of the ages of the plants themselves. Most are still pneumatic and to a lesser extent hardwired. (analogue) electronic. Distributed control systems (DCS) only exist in the most recent installations and then usually in decoupled units. It is sometimes difficult to upgrade control systems in modernization of closely coupled units.

Technical Support—Technological expertise is waning throughout the chemical fertilizer subsector. This is true not only for the individual enterprises but also for the technical institutes that were established to support these industries. It affects not only the knowledge base for operating the plants but also the capability to conduct effective feasibility studies for facility and plant upgrades and the execution of detailed design work. This derives from several factors including lack of prosperity in the industry, which reduces employment opportunities and attractiveness; reductions in enterprise staff; the small size of enterprises that make maintaining a critical mass of expertise difficult; and general insularity from foreign technology. Included in this decline is the reduction in research and development capabilities. These tend to be skeletal at facilities and essentially idled at support institutions. While this has stabilized somewhat, it has created an increasing dependence on foreign alliances for development and implementation of technology upgrades and replacements. Nevertheless, facility staff continue to demonstrate an extraordinary resourcefulness in managing to sustain and improve production operations—exhibiting creativity that stretches the limited available funding.

General Facility Conditions—Facilities tend to be large and sprawling, albeit many of the facilities visited for this study are among the largest in their respective subsectors. Sites generally range from 300 ha to 500 ha, although several are on the order of 100 ha and less, and one approaches 1,000 ha. Facilities typically comprise a dozen or more plants, each consisting of many workshops, usually with large distances between many related production operations. In most cases, this has necessitated extensive piping systems for distribution of utilities (steam, water, etc.), raw materials, and intermediates. Not only are such distribution systems expensive to maintain—the piping itself, heat tracing, insulation and lagging, and pipe racks—but they add energy inefficiencies for pumping, gas compression, and steam tracing requirements. Such expansive layouts also impact requirements for personnel movement and handling of raw materials, intermediates, and products.

Process Technologies—Although the integrity of many facilities—their plants and infrastructure—is slowly deteriorating due to neglect from lack of funds, the more important but less visible endemic problem is the aging technology base. Process technologies throughout the Basic Organic and Inorganic Chemicals Sector are rapidly approaching obsolescence. Table 7 provides a judgment of the currency of the process technologies based upon extrapolation from the facilities visited for this study. Overall, it is estimated that 70% or more of the technologies are aged to obsolete in terms of competitiveness and operational efficacy; and that only about 20% would be considered to be in the “mainstream” in terms of technology in western countries.

For the most part, the highest percentage of modern technology is in the fertilizer subsector which, not surprisingly, is also a subsector deemed to be one of the strongest in terms of overall financial condition. However, even in the fertilizer subsector, old and deteriorating acid production plants (phosphoric, sulfuric, and to a lesser extent, nitric) threaten the longer term competitiveness of most phosphate-based fertilizers and many nitrogen-based products.

Table 7 provides a “proof statement” for the above-quoted statistics. This a sampling of process plants for the main products that cut across the facilities visited. These production plants were selected because they represent products or production
processes common to a number of facilities. As shown, 55% of these technologies are judged to be obsolete based upon the age of the plant and its process “vintage,” and only about 25% of these plants can be considered to be representative of the “mainstream” of modern western chemicals production. Only a few would vie for state-of-the-art status. However, these are only a portion of the plants visited. Not included are dozens of other less common operating and production units that are currently idled or in preservation. These lines are typically older. In general, the overall sector is judged to be in a somewhat poorer state than shown in Table 7. This is because many of the facilities visited are among the largest and most important in respective subsectors of the Russian chemical industry.

Technical characterization of the nitrogen fertilizer subsector is defined by the installed capacity for manufacture of ammonia, urea, and ammonium nitrate. There are 34 installations in Russia for production of ammonia (total capacity 14.0 million mt/py); among them 30 are large, with a total capacity of 13 million mt/py. Of these, 24% of the latest are of first generation, 67% are of second generation, and only 9% of installations belong to the third generation. Due to the generally poor financial situation of the enterprises, low utilization of installed capacity, and low level of technical support, total consumption of electricity is generally 55% higher when compared with the best western installations. All domestically designed and produced installations are of first generation and require modernization.

Total installed capacity for ammonium nitrate manufacture is 3.2 million mt/py. About 70% of installations were designed and produced in Russia. The capacity of installations of other competitive designs is about 1 million mt/py. The average utilization of the installed capacity is about 45%. Price competitiveness of ammonium nitrate is very low due to the high level of electrical power consumption by the old and deteriorating nitric acid production plants.

Industrial potential for phosphate fertilizers is located at 19 enterprises with total capacity of 4.9 million mt/py of which 4.0 million-mt/py capacity was built prior to 1985. About 40% of installations are evaluated as competitive. Competitiveness of phosphate fertilizer plants is

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Number of Plants Visited</th>
<th>Production Capacity (mt/py)</th>
<th>Dates of Plant Installation or Major Upgrade</th>
<th>Average Plant Agea (&gt;20 Years Old) (%)</th>
<th>Plants Near World “Mainstream”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air separation</td>
<td>11</td>
<td>Not Available</td>
<td>1954-97</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Ammonia</td>
<td>14</td>
<td>4,760,000</td>
<td>1962-95</td>
<td>15</td>
<td>45</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>2</td>
<td>800,000</td>
<td>1984-88</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Ammonium phosphate</td>
<td>11</td>
<td>1,265,000</td>
<td>1976-92</td>
<td>15</td>
<td>45</td>
</tr>
<tr>
<td>Nitric acid</td>
<td>4</td>
<td>865,000</td>
<td>1988-90</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>7</td>
<td>1,290,000</td>
<td>1968-91</td>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>8</td>
<td>3,200,000</td>
<td>1974-82</td>
<td>20</td>
<td>90</td>
</tr>
<tr>
<td>Ureab</td>
<td>4</td>
<td>1,930,000</td>
<td>1968-97</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total of Above Plants</strong></td>
<td><strong>61</strong></td>
<td></td>
<td>1954-97</td>
<td><strong>20</strong></td>
<td><strong>55</strong></td>
</tr>
</tbody>
</table>

Infrastructural Plants

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Number of Plants Visited</th>
<th>Production Capacity (mt/py)</th>
<th>Dates of Plant Installation or Major Upgrade</th>
<th>Average Plant Agea (&gt;20 Years Old) (%)</th>
<th>Plants Near World “Mainstream”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam production</td>
<td>18</td>
<td>-</td>
<td>1940-91</td>
<td>25</td>
<td>NA</td>
</tr>
<tr>
<td>Waste incineration</td>
<td>5</td>
<td>-</td>
<td>1966-96</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td>Wastewater treatment</td>
<td>16</td>
<td>-</td>
<td>1954-92</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td><strong>Total of Above Plants</strong></td>
<td><strong>39</strong></td>
<td></td>
<td>1940-96</td>
<td><strong>20</strong></td>
<td><strong>60</strong></td>
</tr>
</tbody>
</table>

*Table 7. Representative Plant Demographics—Currently Operating Plants*

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Number of Plants Visited</th>
<th>Production Capacity (mt/py)</th>
<th>Dates of Plant Installation or Major Upgrade</th>
<th>Average Plant Agea (&gt;20 Years Old) (%)</th>
<th>Plants Near World “Mainstream”</th>
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<tbody>
<tr>
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<tr>
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<tr>
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<td>1954-97</td>
<td><strong>20</strong></td>
<td><strong>55</strong></td>
</tr>
</tbody>
</table>

a. Rounded to nearest five (5) years.

b. Includes one plant scheduled for startup in 1997.
closely dependent on the technical state of plants for sulfuric and phosphoric acid production. Currently, only 50% of the total 12.0 million mt/yr of sulfuric acid production capacity is in operable condition. The technical state of plants for phosphoric acid production is also very poor. Almost all of the installations have been in operation for more than 20 years.

More investment is needed just to return the fertilizer industry to a cost-competitive position in its own domestic markets. Not only are the investments needed to enhance efficiencies and reduce costs but also they are becoming necessary to improve product quality to meet ever-increasing standards. In almost all cases, Russian technology for fertilizer manufacture can meet the minimal technical standards, but it is increasingly difficult to meet higher quality standards. Sometimes where these can be achieved, it is necessary to derate production capacity to achieve the higher specifications (e.g., higher purity requires additional rectification that limits total throughput).

Investment in technology improvement is also the best way to improve environmental performance. New technology is almost always more environmentally benign. Equally important is that the lack of such investment will lead to continuing loss of market demand and lower production rates. Operation at lower production rates will increase operational inefficiencies, which increase waste (per unit of production) and reduce revenues needed to support investment in environmental projects.

**Chemical Fertilizer Subsector Business Viability**

**Basis of Assessment**

Business viability is defined as participating in the Russian economy in a substantive and sustaining way including most of the following:

- Producing needed goods and services.
- Enhancing the overall balance of trade.
- Providing employment (both direct and indirect).
- Supporting improvement in the quality of life.
- Supporting government funding requirements.
- Offering an attractive investment opportunity.

Without assigning quantitative values, these hold little meaning. However, “substantive” connotes a level of significance that would imply that the fertilizer subsector as a whole would constitute a considerable amount of Russian industry output, and “sustaining” means that the sector represents a long-term component of the economy. To achieve these in a free market, global economy there are several necessary conditions that must typically be met. The five considered most important are:

1. Long-term profitability (return for owners).
2. Current price and cost competitiveness (manageable costs).
3. Technology competitiveness (reinvestment for future price competitiveness).
4. Revenue growth (or in some cases sustainability).
5. Strong cash flow (equivalent).

These are to a large extent interdependent and they apply to both the sector as a whole and the majority of enterprises comprising the sector. Thus, viability must be examined not only in terms of the products but also the enterprises.

The following sections address these characteristics both for the chemical fertilizer subsector and the enterprises that it includes. Unfortunately, little reliable financial data exist either for the products or the enterprises. For the enterprises, this requires verifiable balance sheets, income statements, funds statements, and detailed backup information on allocable cost of goods sold (manufacturing, distribution, etc.) and sales. Such information is not widely available, and what is available may not be in a form that readily lends itself to financial analysis without a great deal of manipulation due to the manner in which business is currently conducted and accounted for. Data on fertilizer sector products and markets are more readily available; however, because of uncertainties in domestic conditions, there is little definitive information supporting projections of internal markets.

Therefore, surrogates have been established to assess on a broad scale the overall viability (potential) of both enterprises and sector components; they might be applied to other chemical industry subsectors. These are listed in Table 8 and reviewed in more detail in the following subsections. Unfortunately, information on these surrogates also is highly variable. Nevertheless, information on these surrogates is generally more available, and reasonable judgment can be made from enterprise contacts. Thus, taken together, they do provide an overall indication of the financial health of the sector.

**Chemical Fertilizer Subsector Viability**

The fertilizer subsector overall can best be described as close to weak, although the sector as it is defined is very diverse with a high degree of variability in the many products. However, there
are strengths, weaknesses, and threats that are characteristic of this subsector as a whole (and to the entire chemical industry in the Russian Federation), as discussed below.

**Sector-Wide Strengths**

- Abundant and diverse sources of raw materials and chemical feedstocks including natural gas, oil, coal, and minerals. However, there are exceptions such as a single source of economically extractable phosphate rock.
- A strong technical base in a number of chemical technology fields such as minerals processing.
- A generally highly qualified, well-trained, and technologically oriented work force that is also low cost.
- A workforce including both management and labor that has developed survival-based instincts for sustaining facility operations with limited resources.

**Sector-Wide Weaknesses**

- An aging, and in some cases obsolete, manufacturing base—most of the production capacity is over 20 years old or older and represents outdated, inefficient technology or utilizes equipment that is past its useful life.
- Highly fragmented industry structure in terms of both the number and regional distribution of enterprises. Most importantly, this impacts the ability to build critical mass in production capacity, which leads to cost efficiencies and, especially, flexibility in managing production levels. At present, only a handful of Russian enterprises have the capacity equivalent to a world class producer of chemicals. The entire industry's revenues only total that of a major international chemicals company.
- Almost complete lack of vertical integration within the sector and linkages in the sector to natural complements outside the sector—this affects the ability for managing supply of raw materials, marketing of products, and providing the obvious synergies of integration of manufacturing steps.
- Lack of widespread international marketing savvy among industry and enterprise management.
- Locating most enterprises with limited access to economic supply and product distribution routes (e.g., few facilities are close coupled to water transport systems, even those located on or near major waterways; rail transport requires double handling for exports).
- General collapse of the institutional infrastructure that supported research and development and provided the linkages to western technological advances.
- Lack of government financial support to jump-start the privatized enterprises and a financial segment that ignores the sector.
- A highly sensitized cultural environment that heavily discounts both foreign initiatives and government interventions as exploitative and self-serving. This clearly strains development of potential opportunities for investment. Unfortunately, this is not altogether unsupported by historical perspectives, especially related to the government and numerous foreign “suitors.” The basic premise of “win-lose” interactions in Russian transactions will be difficult to dispel.

**Table 8. Surrogate Viability Assessment Factors**

<table>
<thead>
<tr>
<th>Factor</th>
<th>(Sub)Sector Assessments</th>
<th>Enterprise Assessments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impending competitive (external) threats</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Price competitiveness</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Export sales ratio</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Strength of domestic market</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Production capacity</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Capacity utilization</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Technology status</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Facility design/condition</td>
<td>-</td>
<td>○</td>
</tr>
<tr>
<td>Enterprise ownership/management</td>
<td>-</td>
<td>○</td>
</tr>
</tbody>
</table>

a. Limited Data.

Key: ●—Principal Factor
○—Secondary Factor
policies in pricing and supply management.

- Installation of significant new production capacity outside Russia in several primary market segments where the fertilizer subsector has traditionally been strong. Notable examples include ammonia and nitrogen-based fertilizers in Latin America, China and Europe. A significant portion of this activity has resulted from the expected collapse of the Russian "low cost, natural gas-based products."

- Potential for unrealistic and unwarranted peripheral investment requirements such as environmental improvements, that have low/no return to the sector enterprises and do not significantly enhance the quality of life.

- Continuing reliance on enterprises to provide “free” social services and community infrastructure (e.g., wastewater and water supply treatment) in addition to employment.

- A continuing weak Russian economy, especially in agriculture. In many respects, this is not so much a lack of demand as it is an inability to pay for needed chemical products.

Unfortunately, the balance of the above factors is clearly driving toward a spiraling deterioration in the viability of the industry overall or at least many of its subsectors and enterprises. Table 9 summarizes the combined assessments of the fertilizer subsector discussed below in terms of current conditions and near-term viability. Short-term viability relates to the next 3-5 years. Long-term viability is considered to be 10 years and beyond.

Clearly, the fertilizer subsector is one of the strongest, but even here the strengths are more linked to short-term viability. The nitrogen-based and complex fertilizers are generally price competitive, at least in terms of domestic prices relative to world markets. There is a large capacity base, and capacity utilization is relatively high—60%-80% for nitrogen products and about 50% for complex fertilizers and potassium salts. The phosphorus-based fertilizers are not as strongly positioned. There is less demand and lower price competitiveness. The technology base is generally much older and exhibits a higher degree of deterioration and inefficiency. The principal issues confronting the fertilizer subsector are:

1. High energy-based production with limited control of supply of electricity and natural gas.
2. Very weak domestic demand.
3. Relatively high distribution costs for exports.
4. Aging and relatively energy-inefficient technology.
5. A single source of apatite.
6. Impending threats of installation of production capacity in eastern Asia, especially China.

In light of these conditions, the prospects for longer term viability based upon current trends are not particularly bright. Revenue growth is expected to be modest, at best, over the near term, making little cash available for reinvestment in facilities. Already a number of smaller facilities have closed, especially ones producing phosphorus-based fertilizers.

Lacking intervention in some manner, it can be expected that the sector will drift into a “shadow” industry. Certainly, a number of main enterprises will survive. However, these will amount to only a fraction of the current number. Most will be unable to compete with the more technologically advanced and cost-efficient western companies or the nationally supported industries in developing countries, especially Latin America, China, and the Far East.

The following actions are needed to stabilize and then revitalize the fertilizer industry:

- Decentralizing and ultimately introducing competition into the natural gas, electricity, and rail transportation monopolies.
- Encouraging and providing incentives for mergers and

<table>
<thead>
<tr>
<th>Table 9. Overall Assessment Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizers</td>
</tr>
<tr>
<td>------------------------------------</td>
</tr>
<tr>
<td>Factor</td>
</tr>
<tr>
<td>Price competitiveness</td>
</tr>
<tr>
<td>Export sales</td>
</tr>
<tr>
<td>Domestic market strength</td>
</tr>
<tr>
<td>Production cost factors</td>
</tr>
<tr>
<td>Production capacity</td>
</tr>
<tr>
<td>Capacity utilization</td>
</tr>
<tr>
<td>Technology status</td>
</tr>
<tr>
<td>Short-term viability</td>
</tr>
<tr>
<td>Long-term viability</td>
</tr>
</tbody>
</table>
acquisitions within the sector and between the sector and other aligned sectors to:

- Create critical production mass.
- Vertically integrate raw materials and product conversions.

- Developing and implementing a program and processes for guaranteeing investments in technology upgrades within the sector for key “infrastructure” chemicals, including ammonia, nitric acid, phosphoric acid, sulfuric acid, and mineral-based products.

- Investing in revitalizing technology development, adoption, and adaptation to create value-added products in specialty and health care chemicals.

Assessment for Selected Fertilizer Products

The following groups of products within the fertilizer subsector were chosen for detailed assessment:

- Nitrogen based.
- Phosphorus based.
- Complex.
- Potassium based.

Fertilizers include nitrogen based, phosphorus based, and combinations of these with sulfur and potassium. Seven indicator chemicals were selected as representative of the fertilizer subsector to examine business viability. These are ammonia, ammonium nitrate (AN), urea, monoammonium phosphate (MAP), diammonium phosphate (DAP), complex 1:1:1 NPK grade, and potassium chloride. Table 10 provides a summary of the production and market characteristics of these products.

Nitrogen-based fertilizers clearly enjoy a premiere position

<table>
<thead>
<tr>
<th>Table 10. Fertilizer Subsector Assessment Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
</tr>
<tr>
<td>Total production (000 mtpy)a</td>
</tr>
<tr>
<td>Principal sector producers</td>
</tr>
<tr>
<td>Sector capacity (000 mtpy)a</td>
</tr>
<tr>
<td>Sector production (000 mtpy)a</td>
</tr>
<tr>
<td>Sector capacity utilizationa</td>
</tr>
<tr>
<td>Capacity utilization trendb</td>
</tr>
<tr>
<td>Domestic market (000 mtpy)c</td>
</tr>
<tr>
<td>Domestic/world price ratioa</td>
</tr>
<tr>
<td>Export/production ratio</td>
</tr>
<tr>
<td>Technology age</td>
</tr>
</tbody>
</table>

- 1996 figures.
- 1994-1997 Key: -- Decline >> 5%
  — Decline ~5%
  o Relatively flat
  + Increase ~5%
  ++ Increase >>5%
- 1996 figures—excludes sector consumption.
- Recent vintage
  -- <25%
  — 25%-40%
  o 40%-60%
  + 60%-75%
  ++ >75%
- Ammonium nitrate technology/nitric acid technology.
- MAP or DAP technology/phosphoric and sulfuric acid technologies.
among all sector chemicals in terms of exports and overall competitiveness. There is a large capacity base for most products and the short-term viability is considered good. However, there are several problems underlying the nitrogen-based fertilizer subsector that will impact its long-term viability as delineated below.

In contrast to nitrogen-based fertilizers, the phosphorus fertilizer segment is not faring well. Plants are generally much older and inefficient (especially for sulfuric and phosphoric acid production); there is a lack of high-quality phosphoric acid and only one supply of apatite. Consequently, price competitiveness is lower. Coupled with low domestic demand, this situation has led to low-capacity utilization, which further exacerbates price competitiveness—a vicious cycle. Potassium-based and complex fertilizers are in better condition, primarily owing to a ready supply of relatively high-purity salt deposits. These also support a growing export market in low-price mined salt, refined salt, and processed products.

Fertilizer Subsector Issues
- Support technologies for production of ammonia, phosphoric acid, nitric acid, and sulfuric acid are aging and generally in a state of deterioration.
- Highly energy-intensive production technologies with limited control of the supply of electricity and natural gas.
- Relatively high distribution costs for exports.
- A single source of apatite.
- Very weak domestic demand due to the inability of the agricultural sector to afford the products.
- Significant impending threats from planned installation of fertilizer production capacity impacting sustainability of exports to current international markets, notably Latin America, China, and the Far East and to a lesser extent, Europe.
- Limited capacity for production of the more value-added fertilizers including diammonium phosphate and enhanced urea ammonium nitrate solution.

3. **Capacity Utilization**—Both actual capacity utilization and utilization relative to other enterprises in the sector at the same period are important. In general, utilization on the order of 50%-65% rate a “o,” << 50% rate a “-,” and >> 65% rate a “+.” Since many products are usually involved, judgment is used in “averaging” these prices relative to the range of products.

4. **Technology Base**—This relates to the age, more importantly, vintage of the process technologies used for manufacturing the subsector products. The issue of installation dates (age) is an indicator, but the real issue is the competitiveness of the technology. In some cases, there has been minimal advance in process efficiency such as synthetic dyes. For multiple products from multiple plants within a facility, judgment is used with an eye toward the importance of the technology to product viability (cost and quality). In general, technology based on the order of 10-15 years rates a “o,” technology much older than 20-25 years rates a “-,” and technology more recent than 15 years rates a “+.” The type of technology employed is also considered to the extent that information is readily available, especially for facilities not contacted directly.

5. **Production Costs**—These result directly from the domestic/world price ratio for each product quoted by each enterprise for 1996/97. Since it is recognized that this can change from year to year, only a gross measure is used. In general, a price ratio on the order of 1.00 is “o,” << 1.00 is “-,” and >> 1.00 is “+.” Since many products are usually involved, judgment is used in “weighting” these prices relative to the range of products.

**Assessment of Viability of Chemical Fertilizer Enterprises**

This section presents the results of an assessment of the relative viability of those enterprises that comprise the mainstream of the chemical fertilizer subsector. The assessment is based upon six criteria described below and relies on data for the indicator chemicals used in the above-mentioned subsector assessments.

1. **Market Segment**—The strength of the market segment within which that enterprise participates. For example, fertilizer is comprised of several market segments: (a) nitrogen based, (b) phosphorus based, (c) potassium based, and (d) complex (combined). Even this is an oversimplification because applications and, consequently, demand for specific types of fertilizers vary widely. The criteria used are identified for each subsector.

2. **Capacity**—This rates the total capacity of the enterprise for each subsector product. The issue is having a critical mass to be able to be flexible in pricing, manage costs, and provide credibility in the marketplace. Both the capacity relative to in-country competitors and world competition are factored into the ranking.
6. **Exports**—The level of exports is used as a measure not only of an enterprise’s competitiveness but more importantly an enterprise’s savvy in international marketing and the ability to insulate production from domestic market vagaries. In this regard, exports are necessary in the short term because of current weaknesses in the Russian economy; and they provide the basis for longer term growth. The higher the level of exports and the higher percentage to developed countries, the better the rating. However, this is loosely applied to avoid inadvertently penalizing enterprises that effectively serve domestic markets. Therefore, in general, exports in the range of 25%-50% rate “o,” <25% rate “-,” and >> then 60% rate “+.” Consideration is also given to the countries of export, if known.

Overall ratings are a rough average of these “scores.” In general, where there is judgment, it is in favor of higher viability.

The ability and attitudes of the top management have a significant effect on the performance of the enterprises, particularly on their ability to survive and adapt to competition in a global market economy. Management capability could not explicitly be considered in this assessment, due to a lack of readily available information. As noted below, however, enterprise management was considered at each of the 15 enterprises visited for this project.

Detailed information gathered from enterprises whose facilities were visited was used to validate this ranking approach. The results are not intended to eliminate enterprises as non-competitive. They only reflect the current conditions and likely future, assuming that current conditions continue to prevail. Again, they address only the relative conditions for each enterprise in the mineral fertilizer subsector not necessarily the overall viability of the enterprise itself, which could manufacture products in a number of subsectors and in other sectors.

A total of 30 enterprises were reviewed that participate in the fertilizer subsector. More than 12 of these have a significant production that also falls into other subsectors. The results of the assessment are presented in Table 11.

In developing these ratings, the criteria as described above were used. The market segment criteria specific to this subsector derived from the relative strength of various domestic and export markets based upon product value:

“+” nitrogen-based fertilizers.

“o” potassium-based fertilizers, complex fertilizers, and diammonium phosphate.

“-” simple phosphates and ammonophos.

Of the 30 enterprises, 12 have been identified as viable, 4 have been rated as uncertain, and the remaining 14 as vulnerable. Most of those rated as vulnerable are in the phosphate-based fertilizer segment.

**Environmental Performance of the Chemical Fertilizer Industry in the Russian Federation**

As is already mentioned above, enterprises producing chemical fertilizers are in relatively better financial condition in comparison with the most enterprises of other subsectors. Though all enterprises are still far below their potential capacities, the decline in their production in 1991-94 was not as sharp as in other subsectors, and starting from 1994/95, they began to improve their financial positions. That gave many enterprises the ability to keep their environmental performance on a generally acceptable level and in some cases even improve it. It helped them, with several exceptions, also to keep their environmental payments at a relatively acceptable level, while these payments became a more and more significant part of operating cost. In the case of exceeding temporary emission limits, payments were made from the profit of the enterprise.

Environmental management of the enterprises visited as a part of this study was competent and professional. In many cases, enterprises have projects prepared to improve their environmental performance. Pollution control equipment was usually in acceptable condition, though the lack of automatic control and monitoring equipment was obvious even at the best plants. Environmental laboratories were also relatively well equipped and carried out routine analyses of the enterprises’ environmental performance. A general problem reported by environmental management is the lack of financing for upgrading control and laboratory equipment and in some cases insufficient attention of higher management to environmental problems until they result in significant financial penalties.

Plant managers generally are not concerned with existing soil and groundwater contamination from previous operations. No cleanup of existing contamination is required now at the enterprises, but in the near future, it could be a factor of significant risk for enterprises. It is certainly of current concern for potential investors. The only enterprise
carrying out a serious remediation program is Bryansk Fosforit, which recultivated 75%-80% of disturbed land.

Air emissions were not reported as a significant environmental problem at the enterprises producing only chemical fertilizers. Enterprises producing methanol and some basic inorganic chemicals (chlorine, soda, and caprolactam), in addition to chemical fertilizers, reported air emissions as a secondary environmental problem. The average total emission per ton of main product was about 3.5 kg with variations from 1 to 8 kg. The main pollutants are carbon monoxide, nitrogen oxides, ammonia, and chemical fertilizer dust. For plants producing sulfuric acid, emission of sulfur dioxide is characteristic. Plants producing methanol and basic organic chemicals in addition to fertilizers emit a relatively insignificant amount of volatile organic compounds.

Wastewater discharges represent the primary problem reported by fertilizer facilities. The quality of water consumed by the enterprises is usually low, but environmental authorities’ requirements on the quality of discharged wastewater are generally strict. Enterprises usually discharge wastewater into surface

---

**Table 11. Enterprise Assessments—Fertilizers**

<table>
<thead>
<tr>
<th>Facilityb</th>
<th>Market Segment</th>
<th>Capacity</th>
<th>Capacity Utilization</th>
<th>Tech. Base</th>
<th>Production Cost</th>
<th>Exports</th>
<th>Overall Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Most Viable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JSC “Azn”</td>
<td>+ + + 0 + + +</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>JSC “Azn”</td>
<td>- + + 0 + + +</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>JSC “Chерновыск”</td>
<td>+ + 0 0 + + +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JSC “Dorogobuzh”</td>
<td>+ + + 0 + + +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kirov-Chepetsky</td>
<td>+ + 0 0 + + +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JSC “Куляйсевазят”</td>
<td>0 0 0 0 + + 0 + +</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>JSC “Минералыфер”</td>
<td>+ + + 0 + + +</td>
<td></td>
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<td></td>
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<tr>
<td>JSC “Siwinit”</td>
<td>+ + 0 0 + + +</td>
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<tr>
<td>JSC “Тогдиялазят”</td>
<td>+ + 0 0 + + +</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>JSC “Уралхл”</td>
<td>0 + 0 0 + + +</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Uncertain</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>JSC “Аzn” Berezniki</td>
<td>+ + - 0 - - 0</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Kemerovskoe JSC “Azot”</td>
<td>+ + - 0 - - 0</td>
<td></td>
<td></td>
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<tr>
<td>JSC “Минералыфер” Rossosh-1</td>
<td>+ 0 - + + + 0 0</td>
<td></td>
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<tr>
<td>JSC “Востокрасны”</td>
<td>- + 0 - - 0 0</td>
<td></td>
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<tr>
<td><strong>Vulnerable</strong></td>
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<tr>
<td>“Almaz” of “Azmredmetzoloto”</td>
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<tr>
<td>Belorechenskoe PO “M.F.”</td>
<td>- 0 - - - - -</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Bryansk Phosphate Fertilizers</td>
<td>- + - - - - -</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>JSC Daglos</td>
<td>- - - - - - -</td>
<td></td>
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<td></td>
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<tr>
<td>JSC “Ефремовск” Chemical</td>
<td>- - - - - - -</td>
<td></td>
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<td></td>
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<tr>
<td>JSC “Ефремовск” Chemical</td>
<td>- - - - - - -</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>JSC “Fosforit”</td>
<td>- + - - - - -</td>
<td></td>
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<td></td>
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<tr>
<td>JSC Chemical Plant “Irgiz”</td>
<td>- 0 - - - - -</td>
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<td></td>
<td></td>
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<tr>
<td>JSC “Корунд”</td>
<td>- - - - - - -</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Meleuzovskoe JSC “M.F.”</td>
<td>- - - - - - -</td>
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<td></td>
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<tr>
<td>Novomendeleesky Chemical</td>
<td>- - - - - - -</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>JSC “Phosphate Fertilizers”</td>
<td>- - - - - - -</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>JSC “Phosphorus”</td>
<td>- - - - - - -</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>JSC “Uваровск” Chemical Plant</td>
<td>- - - - - - -</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>JSC “Uваровск” Chemical Plant</td>
<td>- - - - - - -</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

* a. Product Basis: ammonia, ammonium nitrate, carbamide, ammonium phosphate, diammonium phosphate, simple phosphates, complex (1:1:1), and potassium chloride.
* b. Enterprises shown in Bold were visited during the study.
water bodies, often cannot comply with requirements, and have to pay large fees for surface-water contamination. The fees are even higher if the enterprises discharge wastewater to municipal treatment facilities. The main problems reported by the enterprises, or experts, and investigated during the site visits are:

- Insufficient capacity and overloading of wastewater treatment facilities.
- Low efficiency of treatment.
- Low quality of wastewater discharged by other facilities into the treatment plant.
- Generation of a large amount of sludge during the wastewater treatment process.
- Improper reprocessing and disposal of sludge.

The main pollutants discharged by the enterprises are sulfates, chlorides, dry residue, nitrates, nitrogen ammonia, and in smaller quantities, phosphorus, nitrites, and BOD. Some enterprises discharge relatively insignificant amounts of specific pollutants, such as detergents, iron, methanol, and formaldehyde.

Generation of solid waste is not a matter of significant concern for the fertilizer industry with few exemptions. As a rule, these wastes are not very toxic. However, the total amount of waste generated and accumulated by the fertilizer subsector is very high, particularly for enterprises producing phosphate and potassium fertilizers.

Several enterprises reported large amounts of nonhazardous waste (in 1996, Voskresensk—1.7 million ton; “Silvinit,” Solikamsk—3.2 million ton; and “Uralkalij,” Berezniki—9 million ton). All of these enterprises have problems with waste disposal. In Voskresensk, waste is dumped into a 55-ha landfill off site, and an old dumping site containing over 30 million tons of phosphogypsum is located on site. In Berezniki, waste is disposed of in underground caverns. Accumulation of huge amounts of waste has resulted—103 million tons in Berezniki, 42 million tons at Voskresensk, and 30 million tons at Solikamsk.

At a few enterprises (Korund, Dzerzhinsk and Akron, Novgorod are the largest) toxic wastes of first hazard class, including mercury and spent acids in relatively insignificant amounts, are generated.

The rate of waste utilization at the enterprises of the fertilizer subsector is very low—about 30%. Usually, wastes are disposed of in landfills and dumping sites outside the enterprise’s territory. These dumping sites occupy large areas and are considered to be potential risks for soil and groundwater contamination.

Most enterprises are located in large- and medium-size towns with significant environmental loads from enterprises of other sectors or other chemical enterprises. The main environmental impacts are connected with wastewater discharges and contamination of surface water bodies. The health impacts of the fertilizer industry are considered to be moderate in comparison with the enterprises of the other main subsectors of the chemical industry.

Tables 12-16 provide tabulated data for air emission, water consumption, water discharge, waste generation, etc., in the fertilizer industry in comparison with other chemical subsector facilities. Data for fertilizers appear in bold.

<table>
<thead>
<tr>
<th>Table 12. Percent of Air Pollutants Emitted by Enterprises of the Main Subsectors Without Treatment, and Percent Treatment Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fertilizers</strong></td>
</tr>
<tr>
<td><strong>Emissions</strong></td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Solids</td>
</tr>
<tr>
<td>Gas/liquid</td>
</tr>
<tr>
<td>SO₂</td>
</tr>
<tr>
<td>CO</td>
</tr>
<tr>
<td>NOₓ</td>
</tr>
<tr>
<td>Inorganic</td>
</tr>
<tr>
<td>VOC</td>
</tr>
<tr>
<td>HC</td>
</tr>
</tbody>
</table>

Note: SO₂ = sulfur dioxide, CO = carbon monoxide, NOₓ = nitrogen oxides, VOC = volatile organic compounds, HC = hydrocarbons.
The following parameters were selected with points ranging from one to the maximum shown below assigned:

<table>
<thead>
<tr>
<th>Maximum Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Environmental management capabilities</td>
</tr>
<tr>
<td>• Air emissions/wastewater discharges/waste generation and accumulation</td>
</tr>
<tr>
<td>• Characteristics of the environment at the enterprise's location</td>
</tr>
<tr>
<td>• Environmental impact of the enterprise</td>
</tr>
<tr>
<td>• Worker and public health impacts of the enterprise</td>
</tr>
</tbody>
</table>

Maximum Total: 28

The best environmental performance corresponds to the lowest number of points (minimum 5 points for specific enterprise); the worst environmental performance corresponds to the maximum 28 points for specific enterprise. The most reliable data were obtained at the enterprises visited by the study team. At other enterprises, expert's opinions and assumptions were considered. If no data on some or all aspects of environmental performance were available, average scores were used with a corresponding note. The scoring is shown below, with one point being assigned to the most favorable conditions and the highest number of points to the least favorable.

Environmental Management Capabilities were assessed as follows:

• **Excellent**—Highly professional, well-organized environmental management responsible for overall environmental performance. Modern control and laboratory equipment capable of monitoring all releases of the enterprise.

• **Good**—Professional environmental management responsible for significant environmental activities. Operable and well-maintained control and laboratory equipment, with automatic measuring devices on the main sources of releases.

• **Acceptable**—Well-trained environmental management responsible for main environmental activities. Operable control and laboratory equipment capable of monitoring main releases.

• **Marginal**—Environmental management with limited experience responsible for some aspects of environmental activities. Improperly functioning control and laboratory equipment.

---

### Table 13. Structure of Water Consumption by the Russian Chemical Industry in 1994/95

<table>
<thead>
<tr>
<th>Industry</th>
<th>Water Intake</th>
<th>Water Consumption</th>
<th>Share of Total Consumption</th>
<th>Water Used for Production</th>
<th>Recirculation System Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(million cubic meters)</td>
<td>(%) of Consumed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fertilizers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorine</td>
<td>480/495</td>
<td>508/395</td>
<td>57.0/56.5</td>
<td>87.1/88.9</td>
<td>90.9/92.1</td>
</tr>
<tr>
<td>Soda</td>
<td>173/135</td>
<td>174/129</td>
<td>19.5/18.5</td>
<td>87.4/92.2</td>
<td>84.6/84.3</td>
</tr>
<tr>
<td>Organic Synthesis</td>
<td>126/126</td>
<td>89.8/88.8</td>
<td>10.1/12.8</td>
<td>92.7/n.a.</td>
<td>54.9/n.a.</td>
</tr>
<tr>
<td>Aniline</td>
<td>99.7/66.9</td>
<td>89.6/64.9</td>
<td>10.0/9.3</td>
<td>79.8/92.8</td>
<td>85.1/90.0</td>
</tr>
<tr>
<td>Technical Carbon</td>
<td>11.6/4.7</td>
<td>27.7/17.7</td>
<td>3.1/2.5</td>
<td>79.8/86.4</td>
<td>87.1/90.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>891/828</td>
<td>892/700</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### Table 14. Structure of Environmental Payments for the Russian Chemical Sector in 1995

<table>
<thead>
<tr>
<th>Subsector</th>
<th>Emissions Within Limits</th>
<th>Emissions Over Limits</th>
<th>Natural Resource Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(billion rubles)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subsector</td>
<td>Air</td>
<td>Water</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>0.33</td>
<td>2.08</td>
<td>0.96</td>
</tr>
<tr>
<td>Total</td>
<td>0.45</td>
<td>2.49</td>
<td>1.33</td>
</tr>
</tbody>
</table>
### Table 15. Major Wastewater Pollutant Dischargers From Fertilizer Industry in 1995

<table>
<thead>
<tr>
<th>Pollutant Total, Subsector Total, and Major Dischargers</th>
<th>Discharge (mt)</th>
<th>Pollutant Total, Subsector Total, and Major Dischargers</th>
<th>Discharge (mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe, Total</td>
<td>364</td>
<td>Phosphorus, Total</td>
<td>1,120</td>
</tr>
<tr>
<td>Chemical Fertilizers</td>
<td>137</td>
<td>Chemical Fertilizers</td>
<td>394</td>
</tr>
<tr>
<td>Akron, Novgorod</td>
<td>51.9</td>
<td>Voskresenskie Mineral Fert.</td>
<td>172</td>
</tr>
<tr>
<td>Azot, Novomoskovsk</td>
<td>40.0</td>
<td>Akron, Novgorod</td>
<td>85.8</td>
</tr>
<tr>
<td>Azot, Berezniki</td>
<td>6.90</td>
<td>Azot, Nevinnomysk</td>
<td>43.5</td>
</tr>
<tr>
<td>Nitrogen, Ammonia, Total</td>
<td>5,759</td>
<td>Oil Products, total</td>
<td>443</td>
</tr>
<tr>
<td>Azot, Berezniki</td>
<td>682</td>
<td>Apatit, Kirovsk</td>
<td>36.5</td>
</tr>
<tr>
<td>Akron, Novgorod</td>
<td>521</td>
<td>Chemical Fertilizers</td>
<td>185</td>
</tr>
<tr>
<td>Azot, Novomoskovsk</td>
<td>264</td>
<td>Akron, Novgorod</td>
<td>44.5</td>
</tr>
<tr>
<td>Nitrogen, Nitrates, Total</td>
<td>16,000</td>
<td>Zn, Total</td>
<td>55.3</td>
</tr>
<tr>
<td>Chemical Fertilizers</td>
<td>13,600</td>
<td>Chemical Fertilizers</td>
<td>21.3</td>
</tr>
<tr>
<td>Azot, Kemerovo</td>
<td>7,360</td>
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<tr>
<td>Azot, Nevinnomysk</td>
<td>2,210</td>
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<tr>
<td>Nitrogen, Nitrites, Total</td>
<td>406</td>
<td>Cu, Total</td>
<td>15.8</td>
</tr>
<tr>
<td>Chemical Fertilizers</td>
<td>106</td>
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<tr>
<td>Akron, Novgorod</td>
<td>29.6</td>
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<tr>
<td>Azot, Nevinnomysk</td>
<td>14.5</td>
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</tr>
<tr>
<td>Azot, Novomoskovsk</td>
<td>12.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formaldehyde, Total</td>
<td>113</td>
<td>Mn, Total</td>
<td>10.6</td>
</tr>
<tr>
<td>Chemical Fertilizers</td>
<td>39.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Akron, Novgorod</td>
<td>33.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrites, Total</td>
<td>211</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical Fertilizers</td>
<td>3.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Akron, Novgorod</td>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluoride, Total</td>
<td>614</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical Fertilizers</td>
<td>594</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apatit, Kirovsk</td>
<td>372</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voskresenskie Chemical Fert.</td>
<td>152</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Akron, Novgorod</td>
<td>56.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 16. Wastes Generated by Russian Chemical Enterprises in 1994/95

<table>
<thead>
<tr>
<th>Fertilizers</th>
<th>Chlorine</th>
<th>Soda</th>
<th>Org. Synth.</th>
<th>Aniline</th>
<th>Total (000 mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12,400/10,800</td>
<td>931/1310</td>
<td>658/630</td>
<td>262/162</td>
<td>37.6/35.5</td>
</tr>
<tr>
<td>Class I</td>
<td>0.76/0.40</td>
<td>0.289/0.258</td>
<td>95.7/89.8</td>
<td>0.026/0.135</td>
<td>0.002/0.001</td>
</tr>
<tr>
<td>Cr (6+)</td>
<td>0.090/0.090</td>
<td>96.6/89.8</td>
<td>0.026/0.135</td>
<td>96.7/90.0</td>
<td></td>
</tr>
<tr>
<td>Hg</td>
<td>0.012/0.004</td>
<td>0.168/0.176</td>
<td></td>
<td>0.002/0.001</td>
<td>0.034/0.181</td>
</tr>
<tr>
<td>Pb</td>
<td>0.022/0.018</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class II</td>
<td>9.75/3.85</td>
<td>222/222</td>
<td>0.89/1.6</td>
<td>6.7/3.4</td>
<td>1.5/2.3</td>
</tr>
<tr>
<td>Oil Prods.</td>
<td>1.54/1.5</td>
<td>5.7/5.2</td>
<td></td>
<td></td>
<td>7.2/6.7</td>
</tr>
<tr>
<td>H2SO4</td>
<td>n.d./0.65</td>
<td>11.8/5.7</td>
<td></td>
<td></td>
<td>19.2/5.7</td>
</tr>
<tr>
<td>HCl</td>
<td>62.5/81.9</td>
<td>11.3/13.3</td>
<td></td>
<td></td>
<td>139/81.9</td>
</tr>
<tr>
<td>NaOH</td>
<td>0.9/0.9</td>
<td></td>
<td></td>
<td></td>
<td>11.3/13.3</td>
</tr>
<tr>
<td>Cr (6+)</td>
<td>9.98/4.67</td>
<td>21.2/23.7</td>
<td>554/536</td>
<td>153/70.6</td>
<td>1.5/2.2</td>
</tr>
<tr>
<td>Cu</td>
<td>0.34/0.33</td>
<td>51.3/35.5</td>
<td></td>
<td></td>
<td>51.3/35.5</td>
</tr>
<tr>
<td>Class III</td>
<td>12,300/10,400</td>
<td>688/1060</td>
<td>5.1/9.9</td>
<td>75.7/86.6</td>
<td>24.0/22.9</td>
</tr>
</tbody>
</table>

46
- **Unacceptable**—Inexperienced environmental management with responsibilities divided between several departments. Nonoperable control equipment, no monitoring of the releases.

**Releases Into the Environment.** These criteria consider the total amount of pollutants released into the environment (cumulative emissions and discharges) and production efficiency (specific emissions and discharges per ton of product).

**Cumulative Air Emissions**
- **Low**—Low emissions (less than 75% of average emission for all enterprises within the sector) without hazardous compounds of first or second class of danger.
- **Moderate**—5%-150% of average emission for all enterprises within the sector without toxic compounds.
- **Significant**—150%-250% of average emission for all enterprises within the sector with a minor amount of toxic compounds.
- **High**—250%-400% of average emission for all enterprises within the sector with a moderate amount of toxic compounds (1-5 tons).
- **Major**—Over 400% of average discharges of contaminated wastewater for all enterprises within the sector with a significant amount of toxic compounds (over 5 ton).

**Specific Wastewater Discharges**
- **Low**—Less than 70% of average discharges for subsector.
- **Moderate**—70%-130% of average discharges for subsector.
- **High**—Over 130% of average discharges for subsector.

**Total Wastewater Discharges Into the Surface Water Bodies**
- **Low**—Low discharges of contaminated or treated wastewater (less than 75% of average discharges for all enterprises within the sector), without hazardous compounds of first or second class of danger.
- **Moderate**—75%-150% of average discharges of contaminated wastewater for all enterprises within the sector and significant discharges of treated wastewater without toxic compounds.
- **Significant**—150%-250% of average discharges of contaminated wastewater for all enterprises within the sector with moderate amount of toxic compounds.
- **High**—250%-400% of average discharges of contaminated wastewater for all enterprises within the sector with a significant amount of toxic compounds.
- **Major**—Over 400% of average discharges of contaminated wastewater for all enterprises within the sector with a significant amount of toxic compounds (over 5 ton).

**Specific Wastewater Discharges**
- **Low**—Less than 70% of average discharges for subsector.
- **Moderate**—70%-130% of average discharges for subsector.
- **High**—Over 130% of average discharges for subsector.

**Solid and Hazardous Waste Generation and Accumulation**
- **Minor**—Minor waste generation and accumulation.
- **Low**—Moderate nonhazardous waste generation, without significant accumulation.
- **Low/Moderate**—Moderate waste generation, with insignificant amount of wastes of class 2-3 without significant accumulation.
- **Moderate**—Significant generation of class 4 waste with moderate amount of class 2-3 waste, and moderate accumulation of nonhazardous waste.
- **Moderate/Significant**—Significant waste generation, including toxic waste with accumulation of a moderate amount of toxic wastes.
- **Significant**—Generation of a large amount of waste with a significant amount of toxic waste, including waste of hazardous compound, and significant accumulation of toxic waste.
- **High**—Generation of a large amount of waste with a significant amount of hazardous waste, major accumulation of nonhazardous wastes, and/or significant accumulation of toxic waste, including class 1 waste.
- **Major**—Generation of a large amount of waste including a significant amount of hazardous waste with an accumulation of a large amount of toxic waste.

Overall releases into the environment are calculated as an average (1+2+3+4+5)/3.

**Characteristics of the Environment at the Enterprise’s Location**—This criteria considers the sensitivity of the environment where the enterprise is located, its assimilation capability, and cumulative industrial load on the environment.

- Location in small settlements with high assimilation capability of the environment and low cumulative industrial releases.
- Location in small- and medium-size settlements with relatively high assimilation capability of the environment and moderate industrial load.
• Location in medium-size towns with moderate assimilation capability of the environment and moderate and high industrial releases.

• Location in medium-size and large towns in a sensitive environment (protected rivers, national reserves) with moderate to low assimilation capacity and significant industrial load.

• Location in large industrial cities with low assimilation capability of the environment and high industrial load.

**Environmental Impact of the Enterprise**—These criteria consider the impact of the enterprise on the physical and/or biological environment.

• **Minor Impact**—Insignificant absolute and relative pollutants release into the environment without noticeable existing contamination.

• **Low Impact**—Low absolute and moderate relative pollutants release without significant deterioration of environmental conditions.

• **Moderate Impact**—Moderate absolute, insignificant relative releases of pollutants, including an insignificant amount of toxic pollutants associated with moderate deterioration of environmental conditions.

• **High Impact**—High absolute, moderate relative releases of pollutants, including a moderate amount of toxic pollutants with a high level of existing contamination and high level of occupational and public health impacts.

• **Critical Impact**—High absolute and relative releases of pollutants, including pollutants of first toxicity class, high level of existing contamination with toxic substances, high level of mortality, and low life duration.

**Workers and Public Health Impact of the Enterprise**

• No releases of toxic pollutants and no evidence of chemical enterprises’ health impacts.

• Occasional cases of occupational and public diseases with high probability connected with operations of chemical facilities.

• Proven moderate health impacts caused by chemical facilities’ operations.

• High level of occupational and public health impacts of the chemical industry.

• High level of mortality, low life duration related to the operations of chemical enterprises.

The best environmental performance corresponds to the lowest number of points (minimum 5 points for specific enterprise); the worst environmental performance corresponds to a maximum 28 points for specific enterprise.

According to the criteria specified above, the main enterprises of the fertilizer subsector were divided as shown in Table 17 with an indication of main environmental problems.

The groups are as follows:

• Enterprises with unacceptable environmental performance, critically impacting the environment and occupational and public health, and requiring immediate action. These enter-

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**Table 17. Environmental Performance Ranking of Fertilizer Enterprises**

<table>
<thead>
<tr>
<th>Enterprise Name</th>
<th>Points</th>
<th>Rank</th>
<th>Main Environmental Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group I: Enterprises with Unacceptable Environmental Performance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Korund, Dzerzhinsk</td>
<td>22.7</td>
<td>8</td>
<td>Toxic Wastes/Discharges</td>
</tr>
<tr>
<td>Akron, Novgorod</td>
<td>22.3</td>
<td>9-11</td>
<td>Toxic Wastes/Discharges</td>
</tr>
<tr>
<td>Ammophos, Cherepovets</td>
<td>22.3</td>
<td>9-11</td>
<td>Emissions/Environmental Management</td>
</tr>
<tr>
<td>Apatit, Kirovsk</td>
<td>22.0</td>
<td>12-14</td>
<td>Discharges/Waste</td>
</tr>
<tr>
<td><strong>Group II: Enterprises with Marginal Environmental Performance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azot, Nevinnomyssk</td>
<td>21.3</td>
<td>18-19</td>
<td>Discharges/Emissions</td>
</tr>
<tr>
<td>Azot, Novomoskovsk</td>
<td>21.0</td>
<td>20-22</td>
<td>Discharges/Emissions</td>
</tr>
<tr>
<td>Silvinit, Solikamsk</td>
<td>21.0</td>
<td>20-22</td>
<td>Waste Accumulation/Emissions</td>
</tr>
<tr>
<td>Togliattiazot, Togliatti</td>
<td>21.0</td>
<td>20-22</td>
<td>Environmental Management/Waste</td>
</tr>
<tr>
<td>Shekinoazot, Shekino</td>
<td>20.7</td>
<td>23</td>
<td>Environmental Manag./Discharges</td>
</tr>
<tr>
<td>Azot, Berezniki</td>
<td>20.0</td>
<td>27</td>
<td>Waste Accumulation</td>
</tr>
<tr>
<td>Azot, Kemerovo</td>
<td>19.7</td>
<td>28</td>
<td>Waste Accumulation/Discharges</td>
</tr>
<tr>
<td>Mineral Fertilizers, Meleuz</td>
<td>19.3</td>
<td>29-31</td>
<td>Waste Accumulation</td>
</tr>
<tr>
<td>Kuibyshevazot, Togliatti</td>
<td>19.0</td>
<td>31-32</td>
<td>Waste Accumulation/Emissions</td>
</tr>
</tbody>
</table>
Enterprises were ranked as 22-28 points.

- Enterprises with marginal environmental performance, significantly impacting the environment and/or occupational and public health, requiring significant improvements of environmental performance, both in terms of short-term improvements in environmental management and control of releases. These enterprises were ranked as 19-21.3 points.

- Enterprises with acceptable environmental performance, requiring modest, short-term improvements in their operations. These enterprises have less than 19 points.

Obviously, the best enterprise in terms of environmental protection is one that does not operate (and has no contamination from previous operation). Considering that some enterprises are operating now at 10%-30% of capacity, the overall picture of chemical enterprises’ environmental performance could be very different if the economy of the country and chemical industry recovers. In that case some of the enterprises from the third group would move to the second, and enterprises from the second group would move to the first. Small enterprises are not presented in this ranking, but all significant enterprises are included.

Enterprises not presented in this table would fall into the third group—those with acceptable environmental performance. All large enterprises presently in this group have significant environmental problems, but these problems can be solved without critical changes in technology or environmental management.

Enterprises of the fertilizer industry that ranked as members of the first group produce not only fertilizers but also organic synthesis products and methanol.

**Conclusions for Short- and Long-Term Viability of the Chemical Fertilizer Subsector**

**Short Term**—The short-term viability of fertilizers is linked to nitrogen-based products and, possibly complex fertilizers. Continuing price-competitive exports are the key.

Measures must be taken to ensure adequate supplies of natural gas and electricity at reasonable prices. Phosphate-based products represent a more significant problem. Continuing retrenchment and consolidation are needed and expected. As previously reviewed, almost all of the remaining phosphorus-based plants may be closed or severely downsized over the next few years.

**Long Term**—Recovery of the domestic market is essential for long-term viability because of a lack of significant investments to rebuild a world-class, efficient, cost-effective technology base. Restructuring of the industry is also a necessity to create both critical mass within enterprises and vertical integration to more effectively manage production resources and raw material supplies. Significant investments are required in ammonia capacity, enhanced nitrogen fertilizers, and nitric acid and phosphate-based fertilizer technology (especially, phosphoric acid and sulfuric acid), and higher value products (e.g., diammonium phosphate). Finally, more supply flexibility is needed in phosphate rock. The current monopoly is constraining the industry.

**Conclusions**

The fertilizer subsector faces a variety of problems that threaten its viability and ability to compete in world markets. Once overseen by the Ministry of Chemical Industry, which was responsible for planning and investment decisions within the sector, it is now under the purview of a department within the Ministry of Economy. Though the Ministry continues to be involved with the sector through the provision of advice and is in the process of writing a plan for the sector’s development, “The Strategy of Development of the Chemical Complex till 2005,” the government has allocated only very small amounts of funding, and no longer plays a leadership role in the sector. This is true despite the fact that the government often holds minority ownership stakes in chemical enterprises. More importantly, the small amount of capital investment made during the last decade of the Soviet period has left the sector with outdated technology.

Chief among the fertilizer sector’s problems is its extreme fragmentation, which resulted from the privatization of each chemical plant as a separate enterprise. Russian fertilizer companies lack the economies of scale of their foreign competitors, and the output of the largest firms is but a fraction of that of the largest international chemical companies. There are too many enterprises trying to serve the same segment of the market. A lack of vertical integration also hampers the fertilizer subsector. Historic linkages between suppliers and producers that may have existed during the Soviet period have been broken through the privatization process and have not generally been replaced either by integrating suppliers and producers into one firm or by integration through long-term contracts.

As noted above, the technology used by the fertilizer subsector is generally outdated. At least
70% of the technologies used in the chemical industry in Russia are aged or obsolete. Much of the technology dates from the 1970s, as capital and research and development investment in the sector declined during the 1980s. The condition of the fertilizer subsector, though, is somewhat better, with nitrogen fertilizer plants averaging 18 years in age. Nevertheless, chemical processing technologies used in Russia are considerably older than in leading industrial countries, where they typically are renewed on a cycle of 7-8 years or less. Maintenance has also generally been lacking for a number of years and has been focused on keeping critical plant equipment running. Parts are cannibalized from idled equipment when necessary.

The fertilizer industry also faces a variety of problems that are common to industry in Russia. Lack of working capital has led to a large amount of indebtedness to suppliers of the sector and indebtedness to the sector from its domestic customers. The result of this has been the widespread use of barter transactions, refusal of raw material suppliers to provide their products until paid in advance, use of tolling arrangements, and emphasis on production of products for export for which payment is in hard currency.

Plants are often poorly located in relation to the markets they serve and the source of raw materials because transportation costs were not considered properly during the period of state planning. Rail transport in Russia, the dominant mode of transportation for chemicals, costs as much as in Europe and 50% more than in the United States. Plants also have low energy efficiencies because energy was not priced at market rates when the plants were built. With industrial costs for electricity and natural gas in Russia at or above prices in other parts of the world, the sector is extremely vulnerable to energy prices, which today account for nearly a quarter of production costs. This vulnerability is particularly acute for nitrogen-based fertilizers, which are manufactured from natural gas. While the government has taken some steps to control transportation and energy costs, further actions are still needed.

Finally, significant changes are needed to revitalize the fertilizer industry financially and environmentally (these changes are also necessary for most chemical industry subsectors). Changes are needed to restructure the fertilizer subsector as a whole and to restructure individual chemical enterprises. The most important changes needed to revitalize the fertilizer subsector financially are:

- Consolidation of enterprises, both horizontally and vertically.
- Modernization of the manufacturing base.
- Control of natural gas, electricity, and rail transportation monopolies.
- Development of domestic markets.
- Promotion of foreign and domestic investment.
- Indemnification of new investors for environmental contamination existing prior to their investments.

Several significant changes are needed to improve the environmental performance of the fertilizer subsector and ensure that resources spent on environmental problems are effective:

- Establishment of regional hazardous waste treatment facilities.
- Remedial action program to identify and at least contain the most significant soil and groundwater contamination at fertilizer enterprises.
- Upgrades of air and water pollution controls at enterprises.
- Revision of existing ambient air and water quality norms to make them consistent with international practices.
- Establishment of minimum technology-based emission limits for new or modified installations.
- Training in environmental management systems and waste minimization at the enterprise level.
Introduction

Industry worldwide uses very large quantities of phosphoric acid, mainly for production of the concentrated phosphatic fertilizers necessary to obtain a high level of crop yields in agriculture. These include complex fertilizers containing NP and NPK as well as triple superphosphate (TSP). Smaller but also considerable quantities are used for production of sodium tripolyphosphate (STPP) for manufacture of detergents. Annual use of mineral phosphates as P\(_2\)O\(_5\) is about 27 million mt throughout the world. About 24.5 million mt of this P\(_2\)O\(_5\) is used to produce fertilizers and about 2.5 million mt for other technical purposes, mainly for production of various detergents. The major source of phosphates for production of phosphoric acid is deposits of natural phosphates occurring all over the world, which are mostly calcium phosphates. Unfortunately for production of phosphoric acid, the only useful portion is the phosphate ion (PO\(_4\)\(^{3-}\)), while the calcium ion (Ca) produces a waste byproduct. Phosphoric acid is produced almost exclusively by the wet process route through direct reaction of sulfuric acid with ground phosphate ore. In the process the calcium ion becomes combined with the sulfate ion (SO\(_4\)\(^{2-}\)) in the form of calcium sulfate dihydrate (phosphogypsum). The gypsum is separated by filtration, and the phosphoric acid is directed to further processing. The amount of phosphogypsum produced per metric ton of P\(_2\)O\(_5\) is very large—as much as 5.5 mt, of which about 4 mt is solids and the rest is water. Phosphogypsum usually includes about 25% free water. Hence, 150 million mtppy of dry phosphogypsum is generated throughout the world by the production of 27 million mtppy P\(_2\)O\(_5\).

Production of Wet Process Phosphoric Acid in Poland

Three chemical plants produce wet process phosphoric acid in Poland:

1. Z.Ch. “Police” S.A. in Police for production of NP and NPK fertilizers.
2. GZNF “Fosfory” Sp z o.o. in Gdański for production of TSP.
3. Z.Ch. “Wizów” S.A. in Bolesławiec for production of technical phosphates, mainly STPP for detergent industry.

A brief description of each plant follows.

GZNF “Fosfory”
The GZNF “Fosfory” plant contains a phosphoric acid unit with a design capacity of 110,000 mtppy as P\(_2\)O\(_5\). Operational capacity is lower because of the limited area available to dispose of phosphogypsum generated. North African phosphate rocks are the raw materials for production of phosphoric acid in the plants. The dihydrate process is used. The quantity of phosphogypsum generated depends on the amount of phosphoric acid produced and usually amounts to about 350,000 mtppy.

Z.Ch. “Police” S.A.
The Z.Ch. “Police” S.A. plant has four phosphoric acid units with total capacity of 470,000 mtppy of P\(_2\)O\(_5\). The raw phosphates used in the plants are phosphorites from the basin of the Mediterranean Sea, mainly from the north African countries of Morocco and Tunisia, as well as apatite from the Kola Peninsula in Russia. The dihydrate process is used in the plant, which means that phosphogypsum dihydrate (CaSO\(_4\)\( \cdot \)2H\(_2\)O) is generated. The quantity of phosphogypsum generated depends on the production of phosphoric acid and the quality of the phosphates used.

Z.Ch. “Wizów” S.A.
The Z.Ch. “Wizów” S.A. has one phosphoric acid unit of about 30,000 mtppy of P\(_2\)O\(_5\) capacity. The acid produced is an intermediate for manufacturing technical-grade phosphates: orthophosphates of sodium and ammonium, disodium pyrophos-
phosphate, and in particular sodium tripolyphosphate (STTP). Kola apatite is used exclusively for digestion because of its relative purity, which is desired for manufacture of phosphoric acid used for production of phosphatic salts of technical grade. The hemihydrate process is used, modified by admixture of a crystal shape regulator. The factory generates about 100,000 mtpy of phosphogypsum.

Utilization of Phosphogypsum in Poland

The production of wet method phosphoric acid started in Poland in the late 1960s. The three plants discussed went on stream about the same time, and in 1972 management began to seek ways of utilizing the phosphogypsum. The research work was tailored to particular plants depending on their situation, which included location, technology, and raw phosphate type and source. The GZNF “Fosfory” plant was the first to seek ways of solving the problem of phosphogypsum disposal, because the site for dumping the gypsum was about 20 km upstream from the plant on the Vistula River.

GZNF “Fosfory” Plant Utilization for Sulfuric Acid and Cement Clinker—The GZNF “Fosfory” plant is located in the very northern region of Poland where industrialization was being developed at the time. There were no deposits of natural limestone for producing the cement needed for development. Therefore, an early feasibility study focused on the utilization of phosphogypsum to produce sulfuric acid and cement clinker.

The sulfuric acid would be recycled to the production of phosphoric acid and the clinker processed to cement for sale. A similar installation was constructed in the 1970s at Phalaborwa in the Republic of South Africa mainly for recovery of sulfur, which was in short supply.

The GZNF “Fosfory” plant undertook cooperation with a German firm, Krupp-Koppers, for implementation of the project. However, the results of the study showed that the production cost would be considerably higher than the value of the products. Moreover, the production of sulfuric acid and portland cement from phosphogypsum would negatively affect the environment of that coastal region of the Baltic Sea. Emission of dust and gaseous sulfur compounds in this industrialized and heavily populated area would not be desirable. These factors caused the plant to abandon the project. After some time, the installation at Phalaborwa was also shut down due to high costs of production and availability of sulfur from imports.

During the period 1974-77, a series of technical studies focused on the possibility of constructing an installation in the Fosfory plant for granulation of phosphogypsum for use in cement plants. The demand from all cement plants in Poland at the time was high, even above the quantities of gypsum generated in this plant. However, it appeared that the production cost would be higher than the price of natural gypsum from deposits that are very abundant in Poland. During 1976/77, some projects were initiated to use unprocessed raw phosphogypsum in the cement industry. At first, some Polish cement plants began to use raw phosphogypsum from the Fosfory plant. Then the supply of natural gypsum began to rise, and by 1983 all cement plants had discontinued the use of phosphogypsum. In 1975 research was conducted for utilization of phosphogypsum in the production of cellular concrete. A cellular concrete producer used the material for several years but later switched to natural gypsum due to improved plant operation.

Gypsum Building Materials—As far back as the early 1970s, a number of research institutes and technical universities did research and development work on direct utilization of phosphogypsum in production of building materials such as plasters, dry mortars, and construction materials. However, the economic analyses revealed after some years of research that costs of utilization of phosphogypsum are too high when compared with use of natural gypsum even when using the simplest method of neutralization with quick lime. Moreover, there would be considerable emissions of dust and disposal of wastewater to the surrounding environment.

It was stated during the studies performed that processing of the phosphogypsum is not financially viable, mainly due to the high consumption of energy and the necessity to install large systems to protect the environment against pollution evolved during such processes. The high energy consumption is a result of large amounts of water that must be removed from phosphogypsum, detrimental impurities (particularly soluble fluorine compounds), and a very small particle size of about 100 μm. An additional problem arises from the contamination of phosphogypsum by radioactive elements existing in phosphorites used. Only phosphogypsum generated from digestion of Kola apatite, which is very low in radioactive elements, may be used directly to produce building materials destined for dwelling purposes. According to the research,
phosphogypsum generated by processing of phosphorites (of sediment origin) might be directly mixed (maximum of 5% by weight) with other materials in the production of cement and cellular concrete.

**Other Purposes**—In addition to research on utilization of phosphogypsum for industrial purposes as a substitute for natural gypsum, trials were conducted on applying phosphogypsum in the following:

- Civil works.
- Highway construction for stabilization of loosely bound materials, especially in mixes containing fly ash.
- Production of building materials in mixes with ash from coal burning.
- Sealing surfaces of fly ash dumps.
- Reclaiming and improving salinated soils.
- Agriculture to help control humidity of sandy soils and as a filler to dilute concentrated organic fertilizers.

Limited quantities of phosphogypsum were utilized in coal mines as follows:

- For removing of radioactive elements, mainly Ra 226, from mining waters.
- As an agent against explosions of coal dust in coal mines.
- For reconsolidation of mining shafts.
- As insulation in mining operations.

Some other projects were developed for implementation but have been abandoned due to the poor financial situation of the Polish coal mining industry.

Total utilization of phosphogypsum from the GZNf “Fosfory” plant is given in Table 1.

**Table 1. Utilization of Phosphogypsum From GZNf “Fosfory” Plant**

<table>
<thead>
<tr>
<th>Year</th>
<th>Utilization of Phosphogypsum (% of total production)</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>1.8</td>
<td>Cement industry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coal mining</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reclaiming of salinated soils</td>
</tr>
<tr>
<td>1996</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>2.2</td>
<td></td>
</tr>
</tbody>
</table>

**Z.Ch. “Police”**

The situation of Z.Ch. “Police” as related to phosphogypsum management is quite different from that at the other two phosphoric acid plants in Poland. The Z.Ch. Police plant produces nitrogen and phosphates and has suitable land for disposal of phosphogypsum in an area near the plant. Ammonia and carbon dioxide are also produced.

**Utilization for Ammonium Sulfate Production**—To take advantage of these conditions, the Z.Ch. “Police” performed a feasibility study during the late 1970s and early 1980s for processing phosphogypsum into ammonium sulfate and calcium carbonate for agriculture. The plant was to implement the project in the mid-1980s, but at the end of the decade it was canceled due to high unprofitability. Following this, the Z.Ch. “Police” plant undertook a simpler method of using phosphogypsum, i.e., using it in production of building materials.

**Building Materials**—Collaboration was established with a German firm, Salzgitter, which carried out complex tests of building materials made from Police’s phosphogypsum. The initial results were positive, but the detailed economical analysis performed in the study showed that the project would not be competitive with natural gypsum excavated in the valley of the Nida River (south region of Poland). Thus, the project was abandoned.

**Highway Construction Materials**—Further research was directed to utilization of phosphogypsum in highway construction:

- In 1992 tests were conducted in a nearby power plant on the possibility of using phosphogypsum mixed with fly ash from this plant. However, testing carried out by the German partner did not give positive results.
- In 1993 a Polish research and development center carried out a large project regarding utilization of phosphogypsum for production of pavement slabs. Tests performed showed the usefulness of the slabs in road construction.
- In the first half of 1994, the Police plant adapted one of their two small phosphoric acid units to process waste phosphogypsum into gypsum with binding properties. The waste solution from recrystallization of phosphogypsum is used in other phosphoric acid units.
- In 1994 the nearby Enterprise of General Construction in Szczecin performed tests for using phosphogypsum in production of pavement slabs, curbstones, and water well
shells. In the same year the Institute of Building Technics issued a certificate for use of the material in the building trade. The technical adaptations performed in the “Police” plant would permit processing about 130,000 mtpy of phosphogypsum, which is about 7% of the total quantity generated in the plant. In 1994 the “Police” plant utilized 120 mt of phosphogypsum for this purpose. In 1995 a 200-m length of inner plant road was made from this material.

Finally, in view of the higher cost of manufacturing an artificial anhydrite in comparison with material of natural origin, the “Police” plant has ceased production of phosphogypsum for use in building and highway construction materials. Use of phosphogypsum from the “Police” plant as a percentage of total production is shown in Table 2 for the years 1994-97.

The “Wizów” Plant

The “Wizów” plant has sufficient adjacent land for disposal of phosphogypsum. Previously, there was an installation for production of sulfuric acid from natural anhydrite.

Utilization for Sulfuric Acid and Cement Production—At the beginning of the 1970s, the plant developed its own method for utilization of phosphogypsum in the production of sulfuric acid. About 500,000 mt of phosphogypsum (on dry basis) was used during 1973-85 in the place of natural anhydrite. This was 38% of the waste phosphogypsum generated in the plant. Use of phosphogypsum for this purpose was discontinued in 1985, mainly due to the increased energy costs and detrimental effect on the natural environment.

Building Materials—The “Wizów” plant collaborated with the Institute of Inorganic Chemistry on a study for processing phosphogypsum into building materials. The study has indicated that this is a good utilization of phosphogypsum. However, proper processing is required because impurities adversely affect the mechanical properties of the building materials, causing breaking and deformation of final products and increased time for hardening. Binding materials of good quality can only be obtained by purifying and proper thermal treatment of raw phosphogypsum, which considerably lowers the profitability of the process.

The “Wizów” plant is a special case because it uses Kola apatite exclusively, which is very low in radioactive elements but does contain some rare earths. The “Wizów” plant, in collaboration with the Engineering College of Kraków, developed a method for recovery of rare elements by means of digesting the phosphogypsum with a mix of diluted acids. In the process an anhydrite binding material of high quality is obtained as a co-product in addition to a rare elements concentrate. The recovery of rare elements improves the economics of the process. In 1989 studies were made for a pilot unit with a capacity of 16,000 mtpy of anhydrite material and 46 mtpy of rare earths concentrate. The project has not been implemented due to lack of funds.

In 1995 the Institute of Mineral Building Materials branch in Kraków performed a series of tests for using phosphogypsum in production of slow-hardening cement. In 1995 one Polish cement plant used 1,280 mt of apatite phosphogypsum from the Wizów plant.

Table 3 shows the utilization of phosphogypsum from the Wizów plant as a percentage of the total production for the years 1994-97.

Management of Phosphogypsum Stacks

Generally two options are used throughout the world for dumping phosphogypsum:

- Into the sea when a phosphoric acid plant is located close to a vast deep sea with strong tides or currents and winds. In practice that can be only oceans, which would allow a high dispersion of phosphogypsum for a distance of several hundred meters from a disposal place.
- Disposal on land when a phosphoric acid plant is situated far from open sea. Independently of the method of disposal (dry or wet), the construction of stacks must ensure that all effluents from them (both from

<table>
<thead>
<tr>
<th>Year</th>
<th>Utilization of Phosphogypsum (% of total production)</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>0.2</td>
<td>Cement industry</td>
</tr>
<tr>
<td>1995</td>
<td>0.04</td>
<td>Road building and others</td>
</tr>
<tr>
<td>1996</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>0.05</td>
<td></td>
</tr>
</tbody>
</table>
natural moisture of phosphogypsum and from rainfalls) will not infiltrate to groundwater. Most frequently, this is accomplished by a system of drainage ditches with some sort of effluent treatment. Furthermore, in order to lower the dusting of phosphogypsum from stacks as well as to blend them in with the local landscape, reclaiming includes overgrowing the slopes of the stack with grasses and other plants. Long-term research has shown that there are species of grass, bushes, and trees that adapt themselves very well to conditions of a phosphogypsum stack.

**Phosphogypsum generated in the “Fosfory” plant is deposited almost entirely (excluding some quantities utilized economically outside the factory) on a ground stack about 20 km from the factory at the bank of the Vistula River.** The characteristics of the stack are given in Table 4.

**Table 3. Utilization of Phosphogypsum From the “Wizów” Plant**

<table>
<thead>
<tr>
<th>Year</th>
<th>Utilization of Phosphogypsum (% of total production)</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>2.6</td>
<td>Cement industry</td>
</tr>
<tr>
<td>1995</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

Phosphogypsum is transported from the plant to the stack by barges with capacity of 1,000 mt. The phosphogypsum is discharged by means of a movable crane onto a system of conveyors and deposited on the top surface of the stack where it is leveled by bulldozers.

The stack is located on arable land of very high agricultural productivity (a pristine estuary of the Vistula River). Because of the nearness of cultivable lands, there are stringent requirements concerning management of the stack:

1. Minimizing of dust emissions while unloading phosphogypsum from barges and transporting it onto the top of stack.
2. Decreasing of dust emissions from the top surface of the stack.
3. Limiting of infiltration to groundwater of sulfate, fluoride, and phosphate ions leached from phosphogypsum by rainfalls.

Dusting of phosphogypsum from unloading is limited by use of metal covers on the conveyors. The discharging quay is covered with concrete where scattered phosphogypsum is collected and transported to the stack. The emissions of phosphogypsum to atmosphere are minimal and much below environmental standards imposed by local authorities.

Dusting from the stack is suppressed by reclaiming the slopes and sowing of special kinds of grass. After filling a segment of the stack, at least 2 years is required before reclaiming can begin on the slopes. This amount of time is necessary for the stack to consolidate. Estimated amounts of phosphogypsum emitted to the atmosphere are negligible.

Rainfall waters flowing down from the top of stack are collected in a special drainage ditch surrounding the entire phosphogypsum stack. Waters collected flow into a retention pond with a surface (2.4 ha) ensuring strong evaporation of water.

There is a zone of hydrological protection owned by the “Fosfory” plant where only industrial and some grain crops can be cultivated. However, at a distance of about 150 m from the stack, normal agricultural activity can be practiced.

The stack is monitored by measuring the following at a frequency of not less than once a month:

**Table 4. Characteristics of the Fosfory Plant Gypsum Stack**

<table>
<thead>
<tr>
<th>Total Area of Stack (ha)</th>
<th>Total Used Area of Stack (ha)</th>
<th>Height of Stack (meters at sea level)</th>
<th>Disposal of Phosphogypsum (&gt;000 mtpy)</th>
<th>Quantities of Phosphogypsum on Stack (million mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>26</td>
<td>43</td>
<td>300</td>
<td>14</td>
</tr>
</tbody>
</table>
• Chemical analyses of water in banding drainage ditch.
• Momentary depositing of phosphogypsum dust onto boundaries of the protection zone.
• Twenty-four hour sampling of the protection zone and beyond for fluorine compounds.

In addition, there are periodic (minimum once a year) analyses of soils and plants in the protection zone and beyond it and analyses of groundwater and measurements of radioactivity. In the 1970s some trials were made of disposal of phosphogypsum into the Gdańsk Gulf. However, this was discontinued because of the concern of ecologists about further eutrophication of the Gulf by phosphates included in the phosphogypsum.

The “Police” Plant

Almost all of the phosphogypsum produced at the “Police” plant is disposed of on land in a stack because there are no real possibilities to economically utilize any significant amounts in other ways. The characteristics of the stack/disposal area are given in Table 5.

The area encompassing the stack belongs to the “Police” plant and is located on marshy ground near the plant not far from the bed of the Odra River. The phosphogypsum stacking system operates 24 h/day, ensuring continual evacuation of phosphogypsum from phosphoric acid production. Transport is performed by means of conveyor belts in a closed bridge. Phosphogypsum transported directly from phosphoric acid units by the main conveyor is directed to transverse belt conveyors installed on the top surface of the stack. Spreaders are used to throw the phosphogypsum to the end slopes of the stack.

There is a local aquatic environmental protection program, which has a goal of preventing leakage from the stack to groundwater. The method employed depends on lowering the level of surface water on the foreground of the stack. This target is reached by the following system of drainage ditches:

1. Banding drainage ditch about 7 km in total length with depth of around 2 m below sea level.
2. Transverse ditches spaced around the stack at 70- to 100-m intervals between the stack face and banding drainage ditch with the same elevation as the banding ditch.

These transverse ditches differ in length and run 80 to 180 m from the face of the stack on the terrain outside the phosphogypsum stack itself. The total length of the transverse ditches is about 24 km. All effluents collected in the banding drainage ditch are pumped to an in-plant installation for wastewater treatment. The sludges from wastewater treatment not only have neutralizing properties but also fertilizer nutrients and are used for reclaiming the stack. To ensure effective ecological operation of the drainage system, the water level in ditches is kept in a range from 2.0 to 1.4 m below sea level. The system has been working without problems since 1992.

After filling a sequential part of the stack, this new part of the stack’s surface is leveled and reclaimed with the layer of soil or sediments from wastewater treatment. At present about 40% of the stack surface is covered with grass, and of this more than 10 ha is overgrown with trees and bushes—mainly aspen, willow, olive bushes, and Syberian caragane.

Because the terrain underneath and surrounding the phosphogypsum stack is marshy, it was impossible to use an impervious lining of any kind. The peat bog at the foot of the stack was acidic before implementation of the drainage system; it has been corrected, and plants of higher species grow there spontaneously. At present, numerous kinds of birds and other animals live there in the dense growth of shrubbery and trees.

The “Police” plant performs systematic analyses of groundwater through a net of piezometers at a sampling frequency of once per month as well as measurements of the quality of surrounding watercourses once each day in the Jasienica canal.

### Table 5. Characteristics of the Police Plant Gypsum Stack

<table>
<thead>
<tr>
<th>Total Area of Stack</th>
<th>Total Area Used of Stack</th>
<th>Height of Stack</th>
<th>Disposal of Phosphogypsum</th>
<th>Quantities of Phosphogypsum on Stack</th>
</tr>
</thead>
<tbody>
<tr>
<td>(ha)</td>
<td>(ha)</td>
<td>(ha)</td>
<td>(m)</td>
<td>(million mt)</td>
</tr>
<tr>
<td>290</td>
<td>180</td>
<td>95</td>
<td>40</td>
<td>2</td>
</tr>
</tbody>
</table>
or once per month in the water supply canal and navigable canal for the plant. Additionally, effluents from the stack are monitored for volume and composition.

**The “Wizów” Plant**

Recently, almost all phosphogypsum produced in the “Wizów” plant has been disposed of in a stack near the plant. The characteristics of the stack are shown in Table 6.

Beginning in the 1970s, phosphogypsum from the “Wizów” plant was in the dihydrate form. Transition to a hemihydrate method of phosphoric acid production in 1983 resulted in the phosphogypsum becoming a kind of impervious material preventing penetration of rainfall waters into the stack. This protected the groundwater against detrimental impurities from phosphogypsum. In 1992 the “Wizów” plant constructed a new stack in accordance with environmental protection regulations.

The new stack has an impermeable layer at the base to prevent infiltration of effluents into the groundwater. This was especially important during the beginning for building up the stack. The stack also has drainage ditches from which the rainwater flows to a retention pond where it evaporates intensively. Phosphogypsum from the production unit is transported to the stack by dumping cars. Because of its strong hardening properties, phosphogypsum is distributed immediately and continuously over the top surface of the stack by means of heavy mechanical equipment.

The “Wizów” plant regularly performs analyses of groundwater on samples taken once a quarter from piezometers placed around the phosphogypsum stack. Also, once a year the Academy of Agriculture examines the impact of the phosphogypsum stack on surrounding soil and plants. Thus far, there have been no negative results.

An added benefit to producing the gypsum in the hemihydrate form is that dust emissions from the stack are well below permissible levels. The maximum distance of measured impact of the stack on the natural environment with regard to the fallout of phosphogypsum dust (in the amount of 2.5% of permissible fallout of 200 g/m²/y) is 250 m from the stack.

The existence of the stack does not cause any restrictions on use of the surrounding terrain. A characteristic feature of phosphogypsum from apatite is its very low radioactivity. Since the beginning of the 1990s, reclamation has been carried out on the stack’s walls, which were built as final ones. The walls have been covered with a layer of fertile soil where mixes of grass, bushes, and trees have been planted. The established vegetation develops intensively, resulting in the stack blending in and becoming a positive part of the local landscape.

### Financial Charges for Deposition of Phosphogypsum

In 1991 for the first time in Poland, the state authorities imposed fees for economic use of the natural environment. There are fees for the following:

- Emissions of contaminants into the atmosphere.
- Discharging of effluents into surface waters.
- Disposal of industrial wastes.

All wastes generated in the course of industrial activity in Poland are classified into four groups depending on the impact on the natural environment. The level of fees depends proportionally on the number of the group to which a waste is classified. Phosphogypsum generated by production of wet process phosphoric acid is placed in the third group of this classification—disposal of industrial wastes.

The unit charge for disposal of wastes of the third group is substantially high. Therefore, considering an average quantity of 5.5 mt dihydrate phosphogypsum per metric ton of P₂O₅ produced, the financial burden on production costs is significant. The fee is expensive in particular for production of complex fertilizers with high contents of P₂O₅, for example, monoammonium phosphate (MAP) and diammonium phosphate (DAP). Further, disposal of phosphogypsum itself on a stack

### Table 6. The Characteristics of the “Wizów” Plant Gypsum Stack

<table>
<thead>
<tr>
<th>Total Terrain (ha)</th>
<th>Total Area Used (ha)</th>
<th>Height of Stack (m)</th>
<th>Disposal of Phosphogypsum (&gt;000 mt/yr)</th>
<th>Quantities of Phosphogypsum on Stack (million mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>17</td>
<td>35</td>
<td>120</td>
<td>3</td>
</tr>
</tbody>
</table>
is also very costly. Due to the contents of impurities in phosphogypsum that are detrimental to the environment, special technical means must be used for protecting underground and surface waters against leakage from a stack as previously described. Furthermore, extensive and costly measurements and analyses are required. Additionally, those parts of a stack filled completely with phosphogypsum have to be reclaimed. These operations for efficiently protecting the natural environment against pollution are very expensive and substantially increase the production cost of the final products, as do the fees on using the natural environment. For example, the total share of these expenditures amounts to almost 6% of the total production cost of DAP.

**Conclusion**

Phosphogypsum is generated as a waste byproduct of production of wet process phosphoric acid. The calcium content of the raw phosphate and the sulfate ion from sulfuric acid used to digest the phosphate react to form the phosphogypsum.

The phosphogypsum does not cause a problem by itself because it can be utilized economically in smaller quantities in some circumstances as a substitute for natural gypsum. The problem arises because of the large scale of phosphoric acid production and very high unit rate—5.5 mt of phosphogypsum per mt of \( \text{P}_2\text{O}_5 \) produced as phosphoric acid. The high content of water (moisture and chemically combined) in phosphogypsum, about 40\% \( \text{H}_2\text{O} \), compounds the disposal problems. Globally, as much as 150 million mt phosphogypsum is generated per year.

None of the countries producing phosphoric acid have been successful in solving the problem of phosphogypsum utilization in spite of many years of numerous and very expensive research projects. This is mainly due to insufficient demand for the waste or the high cost of processing it to useful products in comparison with use of natural raw materials. Only 2\% of total phosphogypsum generated worldwide finds an economical use. Hence, the problem of phosphogypsum disposal is a global and not regional one.

Phosphogypsum is generally disposed of on land or sometimes in the sea. For disposal on land, a stack has to be properly protected against infiltration of effluents into the aquatic environment. After being totally or partly filled, the stack must be reclaimed so that the only ecological impact would be the change of local landscape.

The only acceptable option for disposing of phosphogypsum generated by phosphoric acid is for purchasers to use their own lands. Importing of phosphoric acid only shifts the problem of disposing of phosphogypsum to an exporting country, which in the global aspect changes nothing.

Since commencing the production of phosphoric acid on a large scale in Poland in the early 1970s, inorganic chemical plants collaborated with specialist research institutes in studying the problem of economical utilization of phosphogypsum. The outcome of these numerous and very expensive studies is a marginal utilization of phosphogypsum (about 0.4\% of that generated).

In the 1980s it became clear among phosphoric acid producers throughout the world as well as in Poland that the only effective solution of the phosphogypsum problem is to dispose of it on ground stacks. Disposal in the sea is possible where very specific conditions prevail.

As a result of the many efforts undertaken by the Polish phosphoric acid industry, a very effective system has been developed for protection of the aquatic environment against intrusion of phosphate, sulfate, and fluoride ions as well as other contaminants from phosphogypsum stacks. Technology has been developed for minimizing phosphogypsum dusting and establishing plant growth on the stacks so that the only impact on environment is a change of the local landscape.

The implementation and management of such a disposal system requires large expenditures. Considering the high unit quantity and high water content (totally about 40\%) of phosphogypsum, the production costs of concentrated fertilizers in such circumstances will no doubt be higher than those experienced by competitors who can dispose of phosphogypsum directly into sea or who are not faced with stringent regulations for disposal in land stacks.
Introduction

The competitiveness of products on the world market is determined by several factors. Cost related to protection of the environment is an important factor. In the context of reform of economic systems in countries in the post-communist period, three types of costs are identified:

- Costs needed to eliminate the ecological load related to the past activities of the enterprise.
- Costs needed to reach a level of environmental pollution due to present activities whereby the production of pollutants corresponds to or is better than fixed standards.
- Costs related to taxes required by the Environmental Protection Fund and set according to the authorized production of pollutants. The investment projects in this field are funded from these means.

The investment cost and operational charges continue to limit competitiveness in the markets during a period when previously neglected modernization and industrial progress require investment in quality, productivity, innovation, and research.

Environmental Problems at Lovochemie

The objective of this paper is to describe the environmental problems of Lovochemie and the measures that have been taken to resolve them. These problems can be divided into the following categories:

- Elimination of the historical load on the environment: cleaning up unauthorized discharges and the plant site.
- Reduction of environmental pollution to values corresponding to fixed limits.
- Establishment of the final position of the enterprise in the field of environmental protection.

The Company

Lovochemie S.A. is an enterprise of medium size, specializing in heavy chemicals and producing industrial fertilizers.

The Facilities

At present, the main production output is represented by chemical fertilizers, which amount to 700,000 mtpy, comprising:

- Ammonium nitrate with chalk or dolomite (calcium magnesium ammonium nitrate) with an annual production of 420,000 mt.
- Ammonium nitrate with urea DAM 390 (urea ammonium nitrate solution) with annual production of 110,000 mt.
- Calcium nitrate with annual production of 60,000 mt.

Ammonia and urea are the main raw materials. They are mostly supplied by Chemopetrol, which is located 40 km from the plant. A substantial proportion of Lovochemie’s production is destined for export to the German and West European markets. It is of superior quality and comparable to European production.

The company is being restructured to concentrate on its core business, i.e., high-volume chemical fertilizers, and to increase the range of compound fertilizers.

The company has sold the plant for manufacturing of chemical viscose, especially velvet silk viscose used for the manufacture of tires. Other non-essential plants, which represent only a negligible proportion of the company’s returns, will be sold.

Geographical Location

From a logistics point of view, Lovochemie benefits from an ideal location. It is situated on the navigable river Elbe, which flows out near Hamburg into the North Sea and has its own seaport. The plant is located where roads and rail traffic lines cross going from Prague to Dresden.
Charactersitics of the Enterprise

Lovochemie is located in the urban area of Lovosice and not far from the town in Lovosice district. It has its own steam and electrical generating plant. Rebuilding is under way and the substantial increase in productivity is contributing to a progressive reduction in the number of staff from 1,800 in 1997 to 950 at the end of 1998. The economic results are related to the dramatic fall in fertilizer consumption in the Czech Republic in 1989, about 30% of its original level, as well as to wide-scale European problems. Annual turnover amounts to between US $76 and US $100 million. The enterprise was privatized in 1996 and since 1997 has been undergoing restructuring and transformation. Among the main shareholders are Unipetrol as a holder of the group of chemical companies and Agrofert, a company that trades in agricultural products.

Environmental Protection After the Second World War

Before the second world war, Czechoslovakia was among the countries that had a high level of industrial development. The change in the political climate resulting from integration of the country into the Soviet communist bloc for many years and central planning of the economy led to a substantial reduction in the industrialization and modernization of the manufacturing plants. Environmental legislation existed, but it was always of marginal interest. Furthermore, it was always possible to obtain exceptions because of the direct management of the economy by political organizations, which had higher priorities in other fields. It was only after 1992 that legal standards began to be put in place, and at present these are being harmonized with those of the European Union. After the 1989 revolution, the Ministry of the Environment and other controlling organizations, which play a key role in the life of the enterprises, were constituted. The activities of organizations such as Greenpeace were also of importance.

The main laws are as follows:

- Law No. 211/1994 on the protection of the atmosphere.
- Law No. 125/1997 on wastes.

The year 1999 is the year during which new limits concerning emissions into the atmosphere (corresponding to those in the European Union) will be fixed for producers of pollutants, as well as corresponding penalties if the authorized quantities are exceeded. The year 1999 will also see the coming into force of new limits concerning the discharge of harmful agents into the water. During the coming years these penalties will increase progressively.

These legislative measures, the activities of the Ministry of the Environment, the pressure of local organizations, and public opinion represent an important motivation for enterprises to invest in this field. In many cases the enterprises must give priority to these investments well before projects for modernization and development.

Ecological Audit and Analysis of Risks of the Lovochemie Company

The law on the transfer of goods (privatization law) covers remediation of the ecological problems caused by previous activities of the privatized enterprise. As expected, the new owner would not assume the responsibilities and costs relative to this load. The obligation to carry out an audit and risk analysis in this respect constituted an integral part of the privatization project.

In the Czech Republic, there are some key industrial zones, which in the past have been heavily contaminated, especially by the activities of the chemical industry. The following enterprises are of particular concern:

- Chemopetrol—Oil processing residue discharged into unauthorized locations.
- Diamo—Discharge of acid waters after the chemical treatment of uranium.
- Spolchemie—The unauthorized discharge of chemical waste as chlorinated hydrocarbons and mercury.
- Tonaso—The unauthorized discharge of chemical waste, especially chrome.
- Ostramo—Crude oil residues.
- Lovochemie—Wastes from chemical plants, crude oil residues.

In view of the creation of discharges containing dangerous wastes over many years, this problem is widespread and serious, especially in relation to the future pollution of subterranean waters all over the country.

The environmental audit of the Lovochemie plant was carried out in 1994 by the specialist company, Aquatest. The objective of the audit was to assess the impact of Lovochemie’s past activities on land, the rock medium, and subterranean water. The costs relating to the elimination of this load were given in the chapter of the audit report devoted to financial questions.
Geomorphology and Hydrography

Lovochemie is located geographically on a plain, at an altitude of 149 m. The river Elbe constitutes the main erosion base. Its flow is relatively stable over the years. Underneath the enterprise site there are 1-5 m of alluvium of different materials. Under these materials are antropoic river sediments whose gravel and sand bed goes up to 10-15 m under the surface. It is constituted of sandy gravel.

The Cenomian layer is represented by sedimentary rock to 80 m. The mother rock of the country is located 600 m under the surface. The aim of prospecting activities was to reach the shallow collector with the free table of underground water at a depth of about 5 m from ground level and linked to relatively permeable sandy gravel. The current flow of underground water is toward the north and northwest where the river sediments can enter the river Elbe.

Methods of Determining Contamination

The Location of the Wells and Forage Technology—To establish a map reflecting the contamination of land and underground water, as well as the direction of flow of the underground water, 24 hydraulic wells and 29 wells were drilled. These wells were installed to serve in the future as monitoring wells.

Pumping Trials—The pumping trials were carried out for chosen wells with a pumping duration of 1 h. The rising level of the water table was checked until it stabilized.

Sampling of Land and Underground Waters—Soil samples were taken at defined depths in the different wells. The following parameters were analyzed:

- Metals, especially Cu, Pb, Cd, Zn, Cr, As, and Hg.
- Extractable nonpolar materials (hydrocarbons from crude oil).
- PCB and chlorinated pesticides.
- Phenols and chlorinated phenols.
- Aromatic hydrocarbons.
- Selected polyaromatic hydrocarbons.

The samples were taken at a depth of 0.7 m to determine contamination at the surface and subsurface level, at 2 m to determine contamination of the central layer, and at the level of underground waters to determine contaminating agents transported by the waters.

Samples of water were taken regularly in all the wells to identify the contaminating agents. In addition, analyses were carried out for samples from all five wells located at the plant. The water analyses revealed the following contaminants:

- Extractable nonpolar materials (crude oil hydrocarbons).
- Phenols and chlorinated phenols.
- Chlorinated biphenyls.
- Chlorinated hydrocarbons.
- Aromatic hydrocarbons.
- Metals, especially Cu, Pb, Cd, Zn, Ni, Cr, As, and Hg.
- Inorganics including ammonia ions, nitrates, nitrites, chlorides, phosphates, hydrogenated carbonates, sulfates, fluorides, Ca, Mg, Na, K, and Fe. The samples were also checked for pH, conductivity, and mineral content.

Assessment of Contamination

There is no law or standard defining the contamination of underground waters or for the producers to assess the degree of contamination. An ecological standard taken from Holland is available in the form of a systematic instruction of the Ministry of the Environment. Contamination is divided into three categories: A, B, and C.

A—Basic.
B—The concentration limits requiring prospecting to determine the sources of the contamination.
C—Levels of concentration for which corrective measures are prescribed.

The decision to proceed with cleaning up does not have a legal basis in the Czech Republic and it is completely under the decision of the Czech Environment Inspectorate.

Results: Land Extractable Nonpolar Materials (Crude Oil Hydrocarbons)—The C limit has been exceeded at the location of reservoirs for fuel oil and benzene, which are above the ground. The land in this area shows a high level of contamination but is still within the limits of values in category B.

Polyaromatic Hydrocarbons—For all the samples, the contamination did not exceed the levels of values of category B.

PCB—Limit B was exceeded in surface and central layers near the transformer, which indicates a leakage of oil from the transformer. The PCB exceeded limit B at the boundary of the plant site. This contamination could be from a source outside the plant.

Metals—Limit C was exceeded in the 0.7 m layer for arsenic (As) near the power plant of the enterprise. It is possible that the source of contamination could be attributed to the “fraisil” (cinders from brown coal). Limit B was exceeded for As below the branch for the plant and also for cadmium (Cd). The other metals exceeded neither limit B nor C.
Conclusion—The main sources of contamination are as follows.

- The oil and benzene reservoirs used in manufacture of NPK fertilizer.
- The transformer (oil).
- The plant’s electric power plant (brown coal cinders).
- The branch-piping for the plant.

Site remediation is required in the contaminated areas polluted by crude oil around the oil and benzene storage tanks near the NPK plant and underneath the power plant. Arsenic pollution was evaluated as of a low importance.

Results: Waters

Nonpolar Extractable Materials (Crude Oil Hydrocarbons)— Substantial pollution was observed around the oil and benzene reservoirs where the C limit was exceeded. The same pollution was observed near the branch-piping for the plant.

The Chlorinated Hydrocarbons—The B limits were exceeded around the degreasing plants where trichlor- and tetrachlorethylene were used, and also around the branch-piping for the plant. Limit C was not exceeded anywhere.

Limit C was not exceeded for PCB. Limit B was exceeded in the area of the oil and benzene storage and near the branch for the plant.

The Metals—Limit C was exceeded for lead (Pb) at one well near the power plant. This was probably due to brown coal cinders.

Inorganic Materials—In view of the type of production, a substantial part of the site had a high salt level. At the point of entry of underground waters, the level of salt was 800 mg/L and at the exit exceeded 2,000 mg/L. Two-thirds of the plant exceeded limit C for ammonia ions.

Regarding fluorine, the pollution occurs in a substantial part of the old plant used for the manufacture of fluorosilicates.

Conclusion Concerning Water Contamination—Cleaning up the water is required in zones contaminated by crude oil around the oil and benzene reservoirs (NPK fertilizer plant) and around the branch-piping. The spilling of fertilizer on the land, the evolution of dust, and eventual infiltration of dust into subterranean water constitute sources of contamination by inorganic contaminants.

Atmogeochemistry

The limit of contamination exceeded category C in the case of crude oil hydrocarbons in the wells near the NPK manufacturing plant and in the eastern part of the plant site.

Risk Analysis

The site remains an industrially usable site. Contamination by inorganic salts does not represent a serious risk. Contamination by nonpolar extractable materials, especially crude oil hydrocarbons, is a risk. Contamination by chlorinated hydrocarbons, especially PCB, was evaluated also as a low risk.

Recommendations and Plan for Cleanup of Plant Site

The recommendations of the audit include cleanup operations around the oil and benzene reservoirs. In view of the area covered by the operations, it is not possible to evacuate the soil and degrade it biologically. The proposed cleanup method is to vent the soil for 6 months and to clean it in situ by rinsing. The monitoring of the situation is an integral part of the program. If after 6 months the concentration of oil hydrocarbons does not decline below limit C, another cleanup technique will be proposed. The eventual discontinuation of the use of benzene for coating in the NPK plant represents a condition of the cleanup programs. The degree of contamination by chlorinated hydrocarbons will be monitored for more than 6 months before making a decision to carry out cleanup work around the plant’s branch-piping. The reduction of contamination by As will be achieved by changing the system of storage of brown coal cinders and cleaning up soil in the areas of highest contamination.

Requests for proposal were issued with the objective of selecting the contractor for the work. The company chosen had developed technology for cleanup operations and presented a proposal at the end of 1997 for implementing it.

Complementary Prospecting

By the middle of 1997, more than a year had passed since the first ecological audit had been carried out. In 1997, complementary prospecting was carried out to observe the possible change of contamination in the areas recommended for cleanup. It aimed especially at the main contaminants, i.e., the crude oil hydrocarbons. Analyses of the level of chlorinated hydrocarbons, polyaromatic hydrocarbons, PCB, and heavy metals were carried out. The samples were taken from existing wells.

The results regarding crude oil hydrocarbon contamination showed that the center of contamination was around the NPK production plant, where a concentration of 3,700 mg/L was measured. In spite of the clear reduction in most of the wells, a substantial increase was noted in one well. Most likely this was due to propagation of the con-
taminants in the direction of circulation of subterranean water.

There was a reduction in the level around the old oil storage area. This is no doubt due to dilution by water coming from the bed of the river Elbe. There was little change in the case of the other contaminants.

Cleanup Technology

The remediation technology consists of pumping out underground waters, cleaning them, and returning them into the contaminated area with a biodegradable protection added. In view of the subsequent contamination in the direction of circulation of subterranean waters, four additional monitoring wells will be constructed in the area of the NPK production plant. The site of the contaminated land area is approximately 75 m x 75 m.

The cleanup pumping from existing wells will begin in the eastern part of the plant’s site. The level of contaminants in the underground waters around the old oil storage has fallen, but the soil still has concentrations of 3–5 g/m³. For this reason the venting method will be used.

Noxious Agents From the NPK Plant

Avoiding the possible saturation of land with benzene used for conditioning NPK fertilizers is an essential condition for the effectiveness of the cleanup operation. In the year 2000, Lovochemie envisages eliminating the direct cooling of benzene used for coating and using the new indirect cooling method (Uhde technology) instead. A coating-benzene balance has been prepared to ensure the sealing of the whole system. However, the balance has demonstrated the leakage of this material into the soil. The entire piping system and storage sites have been checked regularly to measure performance of the sealing.

Where sealing has been damaged, the installation has been repaired.

Costs

The cleanup operation has not yet been completely implemented, but completion is expected in the year 2001. The anticipated cost is US $1 million.

The Lukavec Discharge

The discharge area is located near the southern edge of the Elbe valley in a deserted quarry where chalk has been extracted in the past. The discharge covers an area of about 105,000 m² and is located about 500 m from the commune of Lukavec. For more than 30 years after the end of chalk mining, waste from chemical production was stored in the quarry. In particular, the following materials were stored:

- Cleaning effluent from neutralization of crude oil residues.
- Waste from fertilizer manufacture.
- Brown coal cinders and slag.
- Gravel and construction wastes.
- Soil and filters contaminated by crude oil hydrocarbons.
- Waste from the production of viscose fibers.
- Packaging materials and PVC containers with the remains of contaminating agents.
- Solid waste from the paint manufacturing plant.

The waste was stored in the open air without being protected against water leakage into the underlying layer. In 1993 storage was stopped. The area around the discharge is at present used for agricultural purposes.

The underground water table is located at a depth of 4.5 m. This collector is very vulnerable because it is mostly permeable, sandy gravel. The underground water flow goes toward the Elbe river. Due to leakage of polluting agents from the discharge into underground water, the northern zone of these waters has high concentrations of Na, NH₄, Cl, NO₂, and NO₃ ions.

Risk Analysis

The extent and the level of contamination of the discharge area and the underlying layer were examined by prospecting in 1990 and then again in 1992. The objective of this work was to analyze the stored material and the contamination of underground water and to establish a model of the circulation of underground waters. The monitoring of the quality of the underground waters in defined wells began in November 1994 and has continued to date.

The risk analysis was brought up-to-date in 1997, taking into account the monitoring of the effectiveness of cleanup work and the elimination of the primary sources of contamination. The situation as regards pollution of underground water in and around the discharge area was the main object of the risk analysis and especially of the update. In the stored soil samples and water extracts, the level of fluorides seemed high, exceeding the limit in the C values by a factor of 14 (57 mg/L). The content of crude oil hydrocarbons fell within the range of B and C values. Also, the limits of certain metals such as As (230 µg/L), Cu, and Ni were exceeded.

The quality of the underground water under the storage area was checked only once in the context of prospecting work preceding the cleanup of the discharge. The underground water contained quantities exceeding the limit for chlorides (up to 432 mg/L), NH₄ (336 mg/L), NO₂ (18 mg/L), NO₃ (336 mg/L), NO₄ (18 mg/L), NO₃ (336 mg/L), NO₄ (18 mg/L), NO₃ (336 mg/L), NO₄ (18 mg/L), NO₃ (336 mg/L).
(1,925 mg/L), and F (6 mg/L). Regarding metals, Zn (6 mg/L), Ni, and Al exceeded the limit. Chlorinated hydrocarbons also exceeded the C limit, e.g., dichloroethane, 133 µg/L. The degree of contamination with PCB was within the B value limits. Cyanides were observed to be about 17 µg/L. The hydrological and underground water prospecting showed flow toward the Elbe River. This was confirmed by analysis of contamination in the wells.

The overall mineralization of underground water for the reference value outside the discharge area is about 1,300 mg/L, which is high. Nearer the discharge, it increases to 6,000 mg/L. The underground waters are saturated especially in Na and Cl ions, which is a result of the storage. The NH₄ and NO₂ ions exceeded the C limit by up to 10 times in the area below the discharge. Their concentration diminished as they rejoined the river.

Cleanup: Storage

The old discharge area consisted of five (S1-S5) storage lagoons where contaminated material was disposed of. The wastes and contaminated soils were successively removed from each zone and transferred to the S6 lagoon area, which was constructed in accordance with the authorized environmental regulations. Part of the soil with a low degree of contamination was cleaned up using biodegradable products. The area recovered in lagoons S1-S5 was approved and part of the soil transferred to its place of origin. The area was put back into cultivation in order to be able, in due course, to use the land for agricultural purposes.

Lagoon S6 is a new safe discharge facility comprising a free space for eventual protected storage. The other reclaimed zones have been finally closed.

The closure technology for lagoon S6 involved the following measures:
- The underlying layer of S6 now has the shape and thickness required by Czech standards concerning the closure of dangerous discharges.
- The mineral joint with a thickness of 1 m has been placed in five thick layers on the underlying layer.
- The 2-mm film, which represents the primary barrier, has been placed on the prepared surface. To protect this film against rupture, a geotextile material with a load-bearing value of 800 g/m² has been placed on top of the film. The geotextile material has been doubled (two layers) under the piping.
- A drainage and protection layer of 0.3 m has been added above the geotextile material.

The work carried out has been followed by an organization designated by state bodies especially as regards the placing of insulating layers and the correct implementation in general. Pressure testing and checking of the welds of the seal have been carried out.

Cleanup: The Drainage System

The drainage system is designed as a horizontal network of collectors linked to a manifold conduit. The principal collectors are composed of pipes with a diameter of 300 mm. This pipework ends in a checkpoint outside the discharge where it is possible to monitor the various parameters of gases and rinse the drainage system. The drainage system is linked to the pumping station, which recycles the water into the scrubbing system of Lovochemie. A rainwater collection sewer with an evacuation pipe has been constructed in the drainage system.

Costs


Present Situation: Land

The cleanup began after the calls for proposals and the drafting of the project implementation plan for implementation beginning in September 1994 and ending in May 1997. During the cleanup operations, 350,000 m³ of contaminated soil and waste was evacuated, and 370,000 m³ was handled in total. A capacity of 195,000 m³ was established in lagoon S6 with the eventual objective of storing dangerous waste in the years to come.

Present Situation: Underground Waters

To be able to assess the present situation concerning the contamination of underground waters (in 1998), all the data assembled during the prospecting and monitoring activities during the cleanup were used. In the context of the monitoring operation, the quality of underground waters was followed at 3-month intervals in six basic wells and four reference wells. The degree of water contamination of the discharge was checked at the point of exit of the drainage system into the control point. Continuous monitoring began in November 1994.

The Crude Oil Hydrocarbons—The level of contamination is very low; values exceeding the limits (7,000 µg/L) have been observed only occasionally. In other cases, the values were close to the natural background level.

PCB—Values between the B and C limits were observed only in certain wells; the other concentrations were at the background level.

Volatile Organic Compounds—Contamination has not been observed.
**Metals**—The C limit value is exceeded for Al. The Ni content is at the base level. The Zn values have not reached the B limit.

**Inorganic Ions**—The fluorides level has been reduced to below the B limit in all the wells. Regarding the NH₄, NO₂, NO₃, and Cl ions, the level has decreased substantially. There have been decreases in NH₄ to 260 mg/L, NO₂ to 3 mg/L, and NO₃ to 750 mg/L. These decreases demonstrate the effective elimination of the source of contamination. According to the mathematical model, the eventual removal of the remaining contents by water is very possible in the coming years.

**Risk Evaluation**
The analyses demonstrated a health danger for people in the event of the use of underground water for drinking purposes. There is no risk if the NO₃ level is below 58 mg/L. The NO₃ fixed maximum for drinking water is 50 mg/L. The underground waters in the area are not used as drinking water because the communes are linked to the drinking water distribution system from good-quality sources. Thus, it is not realistic to attempt to reach this level.

The use of underground water for irrigation is unlikely, but reaching the chloride limit of 400 mg/L is also not probable.

**Recommendations**
It is recommended that the present network of wells be kept and the contamination of underground waters monitored at 6-month intervals. In that the level of volatile organic matter is low, it is possible that these could be excluded.

**Conclusion**
- It has been proven, with support from modern technology concerning the transport of contaminating agents, that the water quality of the Elbe River will no longer be threatened by the migration of pollutants contained in underground waters after cleanup.
- The underground waters should not be used either as drinking water or for irrigation due to the nitrate and chloride contents.
- From the point of view of using the site, it is not necessary to plan for the cleanup of the underground waters.

**Other Ecological Loads Due to Lovochemie Activities**

In the context of a responsible approach to the protection of the environment, Lovochemie a.s. Plc. adopted a policy for the protection of the environment with the following objectives:
- By year 2000, reduce the negative influence on all the component parts of the environment, conforming to EU limits and conforming subsequently with the trend toward increasingly strict regulations.
- Resolve for the year 2002 the entire problem linked to the elimination of the old ecological load resulting from the period before privatization.
- Carry out a program of successive modernization of technologies used and make them more ecologically acceptable, with the objective of reducing the negative impact on the environment and at the same time providing the best possible conditions for production.

Regarding water protection, the strategic objective for the year 2002 consists of limiting the volume of residual waters sent to the Elbe River by 20%. To do this, the following means will be used:
- Optimization of the technical process used in fertilizer manufacture.
- The reconstruction of the NPK production plant using new indirect cooling.
- Reconstruction of chemical sewer conduits, which were damaged.
- The reconstruction of the cleaning station for residual waters.

In each situation, the activities will be oriented toward research and the elimination of primary sources of contamination. Lovochemie wishes to participate actively in the program called “The protection of the frontier waters of the Elbe River under the management of the UN and the international committee for the protection of the Elbe.”

Protecting the waters of the Elbe River requires the following actions:
- Degasification of residual waters.
- The scrubbing of the press for crude oil residuals.
- Monitoring of residual waters.
- Adaptation of distribution conduits.
- Reconstruction of sewers.
- Reconstruction of the oil management system.
- Circulation of cooling waters.
The amount of undissolved materials in the effluent has decreased from 310 tpy in 1990 to 208 tpy in 1997. The quantity of phosphates has fallen from 300 tpy in 1990 to 90 tpy in 1997.

Air
The strategic objective consists of achieving stricter limits for the emissions of SO₂, NH₃, and HF, which will be in force from 1999. To reach these limits, the following actions have been carried out:

- The reconstruction of scrubbing stations of the NPK plant, allowing the limits of 50 mg/m³ to be achieved for NH₃ and 5 mg/m³ for HF.
- The reduction of SO₂ emissions and solid parts from the electrical generator of the plant to reach the limit of 2,500 mg/m³ for SO₂ and 150 mg/m³ for solids.

Action to protect the air:
- Reconstruction of coal boilers and installation of gas boilers.
- The installation of a selective reduction unit in order to reduce NOₓ emissions during production of HNO₃.
- The construction of a particulate emission-reducing unit.
- The reconstruction of NPK scrubbing stations.
- The reconstruction of the NPK neutralization equipment.

Between 1990 and 1997, emissions fell significantly, as shown in the following table:

To be able to comply with regional limits, the concentrations of the main harmful agents—especially NH₃, HF, SO₂, and NOₓ—are measured every day at eight measuring points installed around the Lovochemie plant. These data are evaluated, and the state bodies are kept informed about the situation. Regarding emissions within the enterprise, the situation is also checked regularly to maintain and improve the environment in the workplace.

Waste
Regarding waste, at present our strategic objective is aimed at the efficient management of the new Lukavec discharge, the commercial management of its capacity, and the minimization of waste production by several methods including reuse/recycle where possible.

The production of waste is tending to decline as shown in the table below.

<table>
<thead>
<tr>
<th>1990 (tpy)</th>
<th>1997 (tpy)</th>
<th>Average 1990-97 (tpy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total production</td>
<td>88,000</td>
<td>40,000</td>
</tr>
<tr>
<td>Dangerous waste</td>
<td>3,000</td>
<td>400</td>
</tr>
</tbody>
</table>

**Conclusion**
Lovochemie, a Czech private joint-stock company, has been a producer of inorganic fertilizer since 1904, but it is only since the 1950s that production of chemicals has been developed significantly. The owner (i.e., the state) did not seriously concern itself with environmental protection until 1989. Industry was rarely subject to emission limits or rules for waste disposal areas. After the revolution in 1989, strict application of environmental laws was enforced, and the state assumed its environmental responsibilities.

There are several major pollution issues in the Lovochemie case:

- Pollution of soil and underground water in the plant area and the old unauthorized waste deposit at Lukavec near the plant.
- Air pollution, which accounts for a significant portion of the environmental costs. This will be an even more important issue in the future when the Czech Republic joins the European Union.
- Water pollution with significant implication of rising penalties for pollution. The solution for the water pollution problem is oriented toward the minimization of liquid waste rejects in the framework of the “trans-boundary water environmental protection” project.

An environmental audit, as a part of the privatization project, was prepared in 1993, and covered about 60 indices of polluting elements, such as heavy metals, oil and petroleum products, radioactive materials, and organic substances. The analytical results confirmed heavy pollution by motor oil, petroleum (from NPK manufacturing), PCB, As, Cd, and Zn.

<table>
<thead>
<tr>
<th>1990 (tpy)</th>
<th>1997 (tpy)</th>
<th>Average 1990-97 (tpy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>6,500</td>
<td>2,100</td>
</tr>
<tr>
<td>Solids</td>
<td>3,800</td>
<td>54</td>
</tr>
<tr>
<td>NOₓ</td>
<td>3,000</td>
<td>1,000</td>
</tr>
<tr>
<td>HF</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>NH₃</td>
<td>800</td>
<td>220</td>
</tr>
<tr>
<td>Fertilizer production</td>
<td>590</td>
<td>650</td>
</tr>
</tbody>
</table>
Recovery of soil and underground water in the Lukavec area, which began in 1993, was completed in 1997, at a cost of US $8 million. In the plant area the site remediation project, to be completed in 2002, is starting up.

Since 1992 the costs of environmental protection have been increasing. Operational and investment costs for environmental protection rose significantly between 1993 and 1997. The total environmental costs have reached more than US $13/mt of product. The competitiveness of fertilizer production in the Czech Republic is being limited by the high level of environmental investments, which are estimated during the next few years to be of the order of US $5/mt. Costs will stabilize when fixed limits have been reached. The future trend, therefore, should be for those costs to decrease.
**Product Stewardship in the Fertilizer Industry and the Role of National Associations**

Helmuth Aldinger
Director General
European Fertilizer Manufacturers' Association

Introduction

I would first like to express my sincere thanks to IFDC for inviting me to this Workshop. Due to a last minute emergency, I could not be with you and thus asked my EFMA colleague, Mr. Hans van Balken, to present this paper on my behalf.

My presentation will not relate to the world as a whole but will be restricted to examples of product stewardship in the European fertilizer industry. I will approach the subject from a different angle, putting less emphasis on individual company concepts and concentrating more on what the industry does collectively. I will look in particular at the role a trade association such as EFMA plays in this context. Allow me to give you a brief introduction to EFMA.

EFMA represents the major fertilizer manufacturers in Western Europe. Its members account for some 90% of their region’s nitrogen fertilizer production capacity and some 70% of phosphate fertilizer production, resulting in a market share of about 75% of the Western European fertilizer market—European Union (EU) Plus European Free Trade Association.

EFMA’s mission is to identify, promote, and manage the common interests of its members by explaining and promoting the role of mineral fertilizers in European agriculture and horticulture, anticipating and preparing for upcoming issues that may affect the industry, being the industry’s spokesperson and sounding board, and providing its members with a wide range of statistical information and studies. EFMA is an association under Swiss law and has offices in Zurich and Brussels.

The organizational structure is relatively simple and is explained by Mr. van Balken in the Technical Session IV presentation. EFMA’s role is to support the industry’s mission, which can be characterized as follows:

The European fertilizer industry stands for a profitable and sustainable fertilizer industry in Western Europe, safe and efficient manufacturing operations with best available techniques (BAT) standards and a first class environmental performance based on the principles of responsible care, sustainable development, and best agricultural practices. Fertilizer manufacturers also advocate the competitiveness of the agricultural economy; a secure food supply in Western Europe; and an effective world market for fertilizers, their raw materials, and their feed stocks.

Please note that, through its relationship with responsible care, product stewardship can already be considered as part of our mission statement. I will structure my presentation as follows.

First, I will define the concept of product stewardship and address some aspects that are specific to our particular product. Fertilizers differ from the products that are acknowledged to have been implicated in the development of the concept of product stewardship from the beginning.

Next, I will deal specifically with product stewardship programs applied in the European fertilizer industry. I will compare what these have in common with the traditional concepts applied in other industries and thereafter explain some contrasting features. I will address individual fertilizer manufacturers’ actions and contrast them with those that fertilizer manufacturers take in association, mainly through EFMA. I shall then address actions undertaken at the national level. Having tried to assess the performance of the fertilizer industry through its stewarding programs to date, I will conclude by presenting my views on the
future of product stewardship in the fertilizer industry.

**The Concept of Product Stewardship**

**Definition**

The Chemical Industry Association (CIA) in Great Britain defined product stewardship in 1992 as the “responsible and ethical management of the health, safety and environmental aspects of a product from its invention through to its processes of production to its ultimate use and beyond.”

Product stewardship is an integral part of responsible care, which is traditionally defined as “a global chemical industry initiative which calls on companies to demonstrate their commitment to improve all aspects of performance which relate to protection of health, safety, and the environment.”

The European Chemical Industry Council (CEFIC) describes product stewardship as “Responsible Care for Business.”

Responsible care can be considered as a general or global industry initiative. Product stewardship, however, is more precise and focused toward a particular product. Product stewardship programs are therefore specific, detailed, well-documented, and well-communicated initiatives undertaken at individual industry and company levels.

Most importantly, product stewardship is initiated at the top. Management has to demonstrate a strong commitment to product stewardship by ranking health, safety, and environment (HS&E) issues among its highest corporate priorities and maintaining that commitment through continual improvement.

**Focus of Product Stewardship**

The concept of product stewardship is, by definition, applicable to all industries and to all products. It is a cradle-to-grave approach from research to product development; from purchasing raw materials to production, transport, warehousing, and selling; and after the use of the product, often including recycling and reuse.

The fertilizer industry, however, seems to present some particular features, primarily related to the life cycle of nutrients. In the classical nutrient cycle, fertilizer manufacturers assemble nutrients from the biosphere—nitrogen from fresh air and phosphorus and potash from natural deposits. Fertilizers then carry formulated nutrients to production to the start of the food chain. Nutrient-rich wastes emerge from the food chain as livestock manure and sewage sludge from which some nutrients may be safely recovered.

Unlike most products made by chemical processes, manufactured fertilizers do not turn into waste at the end of their “life.” The reentering into the biosphere of the nutrients in these fertilizers, whether directly or via the food chain, has in itself no negative effect on the environment. The potential problem is one of form. For example, is it a nutrient in its original fertilizer form or does it emerge from the food chain as livestock manure or sewage sludge? The problem is one of quantity, concentration, and location, i.e., how much of it there is and where the nutrients reenter the biosphere?

When it is stated, under the generally accepted principles of product stewardship, that the individual manufacturer is responsible for his individual product until it has been put peacefully to rest, this cannot possibly mean that the responsibility of a fertilizer manufacturer extends to his product leaving the food chain again. I do believe, however, that we as manufacturers still must play and do play an important role. After delivery, stewardship of our fertilizer products takes the form of actions to minimize waste and maximize use efficiency. After application, to trace an individual product back to a particular manufacturer would be difficult and, after several seasons, almost impossible. Responsibility for the product tends to become collective. Actions have to be taken in association.

To sum this up, traditional product stewardship concepts can be applied to fertilizers. However, after delivery we are dealing with different issues peculiar to fertilizers. These I will explain in more detail in the second part of my presentation.

**Typical Company Program**

Let us consider a typical company program. The major steps of product stewardship are HS&E information; communication and risk control in the areas of purchasing, production, marketing, and sales; research and development; storage, packaging, and transportation; and the treatment of waste and recycling.

A typical company program starts with a Product Stewardship Policy issued from the senior management, leading to an action plan. A governing body such as a product stewardship steering team is then formed to oversee and coordinate the actions of many individual, more focused product stewardship teams. These would have specific expertise with which to examine and steward single functions or even specific jobs.

The product stewardship policy gives a broad mandate to the individual teams, including the outline of an action plan which, of course, is further refined by the teams.
It is important that product stewardship is not a one-off effort, but an ongoing initiative which can, and will, be linked with other initiatives: for example, major quality initiatives such as total quality management programs or certification initiatives to conform with international standards such as ISO 9000 and 14000.

A good example of product stewardship taken by individual companies concerns the issue of cadmium. The selection of phosphate rocks with high P₂O₅ value and low cadmium content, with a general decrease in P-fertilizer use over the years, has resulted in a reduction in the cadmium applied to West European soils.

A particular feature that distinguishes the European fertilizer industry’s product stewardship programs from those of other industries is the extent to which stewardship actions are taken in association. To illustrate this point, let me give you examples of the substantial efforts made in the area of production, transport, and storage of fertilizers under the EFMA umbrella. A more detailed discussion can be found in the Technical Session IV presentation by Mr. van Balken.

Production

Environmental Reporting

Each year, EFMA members report figures to an outside auditor on the emission levels of their production units. All EFMA producers relate to the production figures, which are graphically displayed. Internal benchmarking of each producer is possible, and it enables them to see whether their performance is in accordance with Best Available Techniques (BAT).

Safety Statistics

EFMA monitors safety performance in a similar way. Here, we use as a performance indicator the lost time injury rate, i.e., the number of accidents resulting in absence from work for 1 day or more per total number of hours worked by all employees. The lost time injury rates are being monitored, not only for the purpose of internal benchmarking, but also to see how the fertilizer sector compares with other branches of the chemical industry.

At the same time, EFMA’s permanent working group on safety is also discussing individual accidents in member company plants and continually trying to extract lessons, which are relevant for all. These discussions start right after an accident, are very open, and result in the wide distribution of recommendations that can improve performance substantially.

Best Available Techniques

In the early 1990s, EFMA established and published BAT criteria for the production of eight fertilizer materials. These products are ammonia, nitric acid, sulfuric acid, phosphoric acid, urea, and urea-ammonium nitrate, ammonium nitrate and calcium ammonium nitrate, NPK compound fertilizers by the nitrophosphate route, and NPK compound fertilizers by the mixed acid route.

The reason for this exercise was twofold: (1) to allow each member to assess how individual plants rate in the context of BAT and (2) to provide criteria to ensure that the highest standards are maintained when a new plant is built or an existing one upgraded. In this way, the BAT criteria make a vital contribution to improving the overall performance of the industry.

In producing our BAT booklets, we were pioneers, and to date four of our BATs, namely, those for ammonia, nitric acid, sulfuric acid, and phosphoric acid, will be directly transferred to the official reference under the Integrated Pollution Prevention and Control (IPPC) Directive of the EU.

Transport and Storage

As another joint effort in product stewardship, EFMA also produced booklets on the safe storage and handling of ammonia nitrate and phosphoric acid. In 1990, recommendations for safe storage and handling of wet process phosphoric acid were issued. Subsequently, in 1992 a handbook for the safe storage of ammonium nitrate-based fertilizers was issued and, more recently, the guidelines for transporting nitric acid were completed.

Safety Data Sheets

Very few fertilizer substances or preparations are classified as dangerous, thus requiring, in accordance with EU directives, the provision of relevant safety data sheets. However, in the interest of good product stewardship and responsible care, and to provide basic product information for the user, model safety data sheets have been introduced for common fertilizer materials such as ammonium nitrate, ammonium sulfate, NPK fertilizers, ammonium phosphate (DAP and MAP), and urea. In 1996, EFMA members’ input in this field was published as “Guidance for the Compilation of Safety Data Sheets for Fertilizer Materials.”

Performance Indicators

In order to sustain its viability, the chemical industry needs to earn an accepted place as a good neighbor. Product stewardship—during the phase of production—therefore also communicates to the public what we do and why we do it. To put it very simply: do good deeds and let people know about them! If our actions, in spite of all our efforts, still have a negative effect on the environment, under
good product stewardship, we have to show that the effects are outweighed by corresponding benefits. The level of public acceptance will provide an indication of how effective we are.

Product stewardship programs do not work only for the common good. An effective program will also bring production costs down by reducing shutdowns and lost time. It will improve raw material or energy efficiency and decrease waste treatment costs. Increased quality will lead to a reduction in customer complaints and off-specification products. Ultimately, efforts will be rewarded and success reflected in the market place.

**Product Stewardship After Sale**

Earlier I remarked that traditional product stewardship addresses recovery of product and waste disposal or recycling; however, with fertilizers this “cradle-to-grave” concept turns into the concept of minimization of waste and maximization of use efficiency. I will now address individual stewardship efforts.

**Stewardship by Manufacturers**

I would imagine that what we do in Europe is basically no different from what is done by other manufacturers, for example, those in the United States; nevertheless, here are some examples. I must stress that I am not advocating any in particular.

The DUPSY software from BASF calculates field requirements for five nutrients in compliance with German fertilizer regulations. The NutriNorm software from DSM generates fertilizer recommendations at the field level in the Netherlands, and a HYDROPPlan software determines fertilizer needs at the farm level in Germany, France, United Kingdom, and the Czech Republic. Manufacturers also provide analytical and diagnostic services including soil sampling to determine nutrient deficiencies in soils and crops: e.g., the KEMIRA soil sampling and analysis service for fertilizer recommendations in Finland and the United Kingdom, and the KEMIRA Nmin service for assessing nitrogen rates in the United Kingdom. Many of these services are becoming more sophisticated with the advance of new technologies associated with precision farming, giving farmers the opportunity to match nutrient supply with site-specific needs in their fields.

Despite the commodity nature of most high-volume fertilizer products, there is considerable scope for product development, which is best illustrated by a wide variety of different specialty fertilizers designed to maximize efficiency and minimize waste. For example, slow-release fertilizers are special nutrient carriers that make nutrients available at a predetermined time or over a prolonged period. Another example is nitrification inhibitors, which as additives for ureic fertilizers are designed to inhibit or slow the natural breakdown of these materials to nitrate in soil.

**Stewardship in Association**

**Code of Best Agriculture Practice**

Once the product is sold, given the common generic features of most fertilizers, producers can most effectively steward fertilizer products in association.

In national, regional, and international fertilizer associations, manufacturers are able to raise collective standards of stewardship by establishing codes of best agricultural practice including quality schemes such as spreader pattern ratings and education programs for farmers or their advisers, extension service workers, and distributors. Some examples follow.

At EFMA, we have most recently established a Code of Best Agricultural Practice: Nitrogen. This code is designed to encourage existing and potential member companies to produce regional codes for use with farmers and advisers in order to comply with the nitrates directive.

In the United Kingdom, the Fertilizer Manufacturers’ Association’s “SP-quality” mark provides the farmer with a means of comparing the physical quality of different straight nitrogen fertilizers in relation to their spreadability.

A good example of an education scheme is the United Kingdom Fertilizer Advisers’ Certification and Training Scheme or FACTS. The message to farmers is that they should only take fertilizer advice from FACTS-registered advisers.

Associations look into environmental and health impacts on a macro scale by commissioning technical studies and investigations. At EFMA, for example, we are currently exploring the beneficial health effects of dietary nitrates by supporting medical research through “in vivo” experiments on gastro-intestinal sensitivity to dietary nitrates.

**Policy Development**

Perhaps most importantly, manufacturers in association are able to set up forward planning studies, not only to assist them with their own operational, strategic, and market planning, but also to provide information for policymakers and relevant authorities. Thus, the industry is able to find a course for fertilizer products, stewarding them through the regulatory process when policy interventions such as fertilizer consumption taxes are being considered, or when policy instruments are being de-
signed (for example, to limit the use of nutrients in environmentally sensitive areas, such as the nitrate-vulnerable zones defined as part of the nitrates directive).

I have already mentioned the series of EFMA BATs established for finished fertilizer products and intermediates. They not only improve the environmental performance of the industry but also provide an example of stewardship, which helps to safeguard the future of fertilizer production from unjustified environmental policy intervention. Such proactive product stewardship not only demonstrates responsible care but also reduces the need for corrective measures later on, which as experience shows are always heavier, more expensive, and burdensome. The idea is to get it right the first time!

This proactive approach has been indispensable during the drafting, amendment, and implementation of key directives and regulations of the EU such as the fertilizer “mother directive,” the so-called nitrates directive, the drinking water directive, and various national regulations covering fertilizer use and fertilizer products.

Establishing and maintaining this dialogue with policymakers and authorities, thus enabling them to make more informed decisions about the production and use of fertilizers, is a significant “raison d’être” for manufacturers’ associations and a good example of product stewardship.

**Conclusion**

Although the fertilizer industry has undergone major restructuring in Europe, there is still substantial involvement by established chemical heavyweights who have the most up-to-date corporate stewardship programs covering all their activities. As a result, I would argue that the product stewardship efforts and performance of the European fertilizer industry match the highest industry standards.

In those areas where the industry acts in association, I hope the examples I have given you speak for the industry’s performance. Can we still do better? Of course, product stewardship is an exercise in continuous improvement.

Let me close with one aspect, which is probably the most important for the industry’s well-being if not survival. In Europe, fertilizers and their impact on the environment have increasingly come under critical scrutiny from the public. Communicating our side of the story will be at the top of the agenda in the coming years. We will increase our proactive product stewardship efforts in policy development and in the regulatory process.

In a society such as ours, policy development does not start with established regulatory bodies but with opinion leaders, pressure groups, and the general public. European fertilizer manufacturers will seek a broad dialogue with these groups, communicating the role mineral fertilizers play in today’s world, improving the image of their product, and winning back the acceptance of fertilizers, which was once enjoyed and rightly deserved in a world where hunger should be a thing of the past.
State of the Art in Cleaner Production in the Czech Republic

Vladimir Dobes
Director
Czech Cleaner Production Centre

Introduction

The promotion of cleaner production (CP) in the Czech Republic began in 1992, and the basic capacity level (BCL) for cleaner production has already been achieved. The BCL for cleaner production is defined by criteria described in this paper. In addition, the framework conditions for CP are described.

Active Core of CP Advisors and Trainers

The Association of Managers for Cleaner Production (AMCP) constitutes a core group of active experts on CP. The AMCP was established by the graduates of the first long-term training program under the Czech-Norwegian CP Project in 1993. The emphasis on the train-the-trainer approach under the CP Project proved to be very effective. The following is a summary of the training results:

There are two basic types of CP training programs in the Czech Republic:

- **Long-term training**—This includes on-the-job training at demonstration sites. This model was first introduced within the Czech-Norwegian Project. This is also an effective model for regional projects.
- **Short-term training**—This constitutes both theoretical and practical aspects of CP. The Czech Cleaner Production Centre (CCPC) offered 4-day workshops with a grant from the United States Environmental Protection Agency (EPA), and 1-2 day seminars were given by the World Environment Center (WEC) and later by the Pollution Prevention Centre (PPC).

Long-term training programs are instrumental for creating a pool of active consultants and trainers. Short-term training programs result in familiarizing people with CP, and they are particularly effective for government officials. Interaction between people from public and private sectors is very important to enhance a learning process.

Set of CP Demonstration Projects

Benefits of cleaner production can be documented on results of 53 demonstration projects implemented in the Czech Republic:

- The following environmental benefits were accrued: emission reduction—2,488 mtpy, wastewater reduction—4.4 mL m³/year, waste reduction—11,126 mtpy, reduction of dangerous waste—10,407 mtpy.
- Financial saving—209 million CZK/year (US $5 million/year) achieved within the first year after implementation of measures.

The financial saving due to housekeeping measures was almost 1 mL CZK/year (US $24,000/year) on average, while the corresponding reduction of waste flow amounted to 25%. The overall saving was about 1%-2% of enterprise turnover. According to the findings by the CCPC) the financial saving mainly comes from enhanced process efficiency; saving on pol-

1. mL = million.
lution control is marginal, only an average of 8%. The current pollution fees and charges are therefore not a strong instrument.

CP demonstration projects were realized within the following programs/projects:

Functioning CP Centers

Czech Cleaner Production Centre
The CCPC was established in 1994 within the framework of the Czech-Norwegian CP Project. CCPC further broadened its operations with the support of the UNIDO/UNEP NCPC Program. CCPC joined the Program in 1995. CCPC has a central office in Prague and a branch office in Brno and implements its projects with teams of professionals from the AMCP. The main areas of activities are demonstration projects, training, policy advice, and information dissemination.

Pollution Prevention Center
The PPC was established in 1995 within the framework of the Waste Minimization Project, which was managed by the WEC. PPC works as a program of the Czech Environment Management Centre (CEMC). CEMC is presently involved in a 2-year “Coaching Program” on Environment Management Systems (EMS) and CP in the Czech Republic and Hungary. This program should prove the advantages of integrated implementation of EMS and CP, which will be conducted in 20 to 40 Czech and Hungarian companies.

Training Materials in the Local Language
A large set of materials on CP is already available in the Czech language. The first two domestic manuals were prepared by the CCPC for the use of industry and government with a grant from the Ministries of Industry and Environment. The manual for industry is designed as background material for short-term training. The whole package includes sets of exercises and simulation games. Most of the materials intended for short-term training are translations of foreign originals.

In addition, a manual on CP policy for municipal authorities was developed and a manual on integration of CP and EMS is being developed by experts from STENUM Graz, an Austrian consulting firm, and consultants from the CCPC within the framework of the UNIDO/UNEP NCPC Program.

CP in University Curriculum
The following three universities have integrated CP into their existing curricula: Economical University, Prague; Technical University, Brno; and Technical University, Ostrava. Two other universities are implementing postgraduate courses in CP—the University of Chemistry and Technology, Prague and Technical University, Zlin. A few other universities have lecturers trained in CP.

Framework Conditions for CP

Factors in Domestic Policy Environment
The most important factors are environmental and market pressures. This was even more evident during the first phase of CP’s introduction to the Czech Republic. The level of public demand is low, mainly due to limited promotion of CP through the media to the general public.

Role of CP Stakeholders

Government—The government has played an important role since the very beginning. The Ministry of Environment is preparing policies and programs for promoting CP. The Ministry was active in establishing a special purpose fund for CP within the State Environmental Fund in 1998. In March 1999 the Minister of Environment signed the International Declaration on Cleaner Production.

The Ministry of Industry and Trade is also active. It supported development of the Study on Instruments Promoting Waste Minimization (CEMC, 1994) and the first domestic CP manual for industry (CCPC, 1997). It also supports integration of CP and EMS. The Ministry of Foreign Affairs plays an important role in initiation and coordination of international projects.

Local Authorities—Local authorities have been playing an important role in promoting CP since 1995/96, when the first three Local Authority Projects were implemented: (1) Industrial Waste Minimization in Decin, (2) EKOPROFIT ZlinCotrokovice, and (3) Cleaner Production for the River Svitava. Demonstration projects were implemented in 23 enterprises in total. Projects (1) and (3) focused on small- and medium-sized enterprises (SMEs).

The CCPC managed these pilot projects with assistance from the UNIDO/UNEP NCPC Program for projects (1) and (2). STENUM, an Austrian organization specializing in training and consulting in the area of environmental management, served as a counterpart organization. STENUM introduced its experi-
ences in the EKOPROFIT Graz Project, a successful regional project implemented by the municipality of Graz, Austria.

Another regional project was implemented in Ostrava in 1997 with financial support from Poland and Hungary: Action for Restructuring the Economy (PHARE). It included training of municipal officials and development of local CP policies. Recently the following two projects have been finalized: in Decin (continuation of the industrial waste minimization project) and “From CP to EMS” in Zlin (continuation of the EKOPROFIT project). Both projects were financially supported by the municipalities of Decin and Zlin. A regional project in Moravska, Trebova, is now being implemented.

Universities—Universities play an important role in the capacity building for CP. The focus is shifting from postgraduate to undergraduate studies. Some undergraduate students have already participated in demonstration projects in the framework of their thesis, which has been very beneficial for all parties concerned.

Implementation of Environmental Management Systems

The aim of CP demonstration projects is to show the benefits of CP and build professional capacities within companies so that they will initiate a process of continuous improvement on CP. This aim is totally met only at those enterprises that have integrated CP into their management systems.

CP and EMS are mutually supportive. While the former focuses on operations, the latter concentrates on management systems. EMS will provide a managerial framework to keep CP progressing in companies. CP, on the other hand, will solidify EMS by providing a tool for continuous improvement of environmental performance and competitiveness. Companies that have started with CP projects can quickly build an efficient EMS. This mutuality of EMS and CP leads to the idea of developing methodology for the integration of CP and EMS.

The first project of this kind in the country started with a small wine producer, Znovin Znojmo, in 1996. The project was financed by the Austrian Government and implemented by STENUM Graz with assistance from the CCPC. The project was completed in 1997 by successful certification against ISO 14001.

Another project that was focused on small enterprises was realized in 1998. The project was implemented by the CCPC in three enterprises in Zlin—two municipal companies (technical services and water supplies and sewerage) and a small building company. STENUM Graz provided its continuous support under the UNIDO/UNEP NCPC program.

Financing of CP

Financing CP Promotion

In the beginning international donors fully financed CP training and demonstration projects. Today, most activities are financed by more than one source. Some of the most important financial resources are:

- International grants, mainly from the UNIDO/UNEP NCPC Program.
- Industry—The industry undertakes an increasing share of the costs. Large enterprises have already been requested to pay the full cost. Small enterprises, however, continue to need financial support from outside sources.
- Municipalities—The municipalities—Decin and Zlin—contributed 40,000 CZK (US $975) and 3,300,000 CZK (US $80,000), respectively, to the continuation of regional projects. The costs of the projects at their first stage were covered only by industry and international grants.
- Project funding donors, such as PHARE.
- Special funds, for example, the regional CP fund.

Financing CP Investments

The CCPC has achieved an agreement with the Ministry of Environment and the State Environmental Fund (SEF) to establish a special purpose fund for CP in the SEF. The fund was opened under the name Cleaner Production Program in early 1998. A CP fund in the SEF facilitates investment for CP measures, which otherwise would be foregone. The establishment of the fund has also elevated CP to a more visible national agenda.
Waste Minimization Program for Fertilizer Plants in Lithuania and Poland

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Introduction

In 1992, the World Environment Center (WEC), with financial support from the United States Agency for International Development (USAID), started work in the Baltic countries of Estonia, Latvia, and Lithuania, as well as Poland, to demonstrate the economic benefits of environmentally motivated low-cost waste minimization and cleaner production measures. This paper discusses the results of 15 waste minimization projects in the fertilizer sector in Lithuania and Poland.

WEC’s Industrial Waste Minimization Program saved the six participating companies over US $868,000/year for an expenditure of US $566,000. Because savings of a similar magnitude will continue in future years, the economic benefits gained by the companies are more appropriately expressed in terms of Net Present Value (NPV). Altogether, the NPV of the economic benefits for the 15 waste minimization projects at the six companies has been calculated at over US $3 million. This is based upon an average project life of 8 years, a dollar discount rate of 10%, and a corporate tax rate of 30%.

By decreasing the use of resources such as water, energy, and raw materials, and by reducing the generation of waste materials, the companies significantly improved their productivity, environmental performance, and worker health and safety.

Indeed, the companies achieved substantial reductions in releases to air, water, and land. Additional environmental benefits associated with decreased water, energy, and raw material use were also realized.

Waste Minimization

Waste minimization is the maximum feasible reduction of all wastes generated at production sites. The hierarchy for waste minimization is shown below:

<table>
<thead>
<tr>
<th>Method</th>
<th>Example Activities</th>
<th>Example Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Source Reduction</td>
<td>Product changes</td>
<td>Change to low-sulfur fuel</td>
</tr>
<tr>
<td></td>
<td>Source elimination</td>
<td>Change to higher quality rock</td>
</tr>
<tr>
<td>2. Recycling</td>
<td>Reuse</td>
<td>Consumption of scrubber liquor in process</td>
</tr>
<tr>
<td></td>
<td>Reclamation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neutralization</td>
<td></td>
</tr>
<tr>
<td>3. Treatment</td>
<td>Incineration</td>
<td>Lime treatment of waste water</td>
</tr>
<tr>
<td></td>
<td>Scrubbing</td>
<td>Fluorine scrubbing</td>
</tr>
<tr>
<td>4. Disposal</td>
<td></td>
<td>Gypsum stack</td>
</tr>
</tbody>
</table>
Incentives for Waste Minimization

There are four major incentives for launching a waste minimization process.

Regulatory Compliance—Implementing an organized waste minimization process will eliminate or minimize the generation of wastes. Industries can comply with existing and future environmental regulations.

Competitive and Technological Advantage—The implementation of a waste minimization process usually results in development of new methods and technologies that provide a competitive advantage over the competition.

Better Employee and Community Relations—By taking a proactive role in implementing a waste minimization process, industries can enjoy a better relationship with their employees, customers, and the neighboring communities.

Financial Benefits: Direct and Indirect—A major incentive for implementing waste minimization is the financial benefit—direct and indirect. The direct benefits usually include savings in raw material, energy, and disposal costs and increased profits caused by increased productivity. The indirect benefits include savings in penalties and liabilities.

The Waste Minimization Program in Lithuania and Poland

Lithuania

The program at LIFOSA (then the Kédainiai State Chemical Plant) started in 1992. The company had begun production of sulfuric acid and single superphosphate (SSP) in 1963 and the next year started production of granulated superphosphate and aluminum fluoride. In 1968 two new plants to produce phosphoric acid and ammonium phosphate (MAP) began operations. The first revamp began in 1975 and ended in 1988 when a new sulfuric acid plant came on stream.

Lithuania had only recently regained independence when the waste minimization program began in 1992. The agricultural sector was in turmoil following the rapid breakup of the collective farms and privatization. Lithuanian farmers could not compete with subsidized Western European farmers, and Kédainiai was forced to cut production to less than 25% of previous levels because of this and fertilizer dumping by the former Soviet Union (FSU) countries.

Despite, or perhaps because of, their problems, Kédainiai adopted the program with enthusiasm. Before independence, a company like Kédainiai had only to meet production targets with little regard for costs or efficiency. This was exemplified by a steam boiler operation that had no meter for fuel consumption.

Six projects were undertaken, each with investments of US $10,000 or under and with paybacks ranging from 1 to 9 months. A major part of the program was the introduction of cost benefit concepts and the calculation of payback and return on investment.

In October 1996, the plant was privatized. Production is now at record levels and emissions continue to be reduced.

Poland

The program in Poland started in 1996 at five fertilizer producers.

LUBON is a compound fertilizer and chemical manufacturer, producing single superphosphate (powder), nitrogen-phosphorous-potassium (NPK) compound fertilizers, sodium polyphosphate, and hydrogen fluoride. The plant produces about 150,000 mtpy of fertilizer (100,000-mtppy powder SSP from two Moritz dens, and 50,000 mtppy of NPK).

POLICE is a large integrated phosphate and nitrogen fertilizer plant, producing sulfuric acid (utilizing the double contact/double absorption process), ammonia, urea, phosphoric acid, nitrogen-phosphorous (NP) and nitrogen-phosphorous-potassium (NPK) compound fertilizers, sodium fluorosilicate, and titanium dioxide. The plant produces over 2 million mt of fertilizer a year and employs 4,500 people.

SIARKOPOL mines and processes sulfur and produces sulfuric acid for fertilizers and battery acid, SSP and NPK compound fertilizers, bleaching earths, aluminum sulfate for water treatment, and cryolite. Cryolite is used in the glass, ceramics, and aluminum industries. The plant once produced over 4.2 million mtppy of sulfur from open cast mines but had to reduce production to 1.5 million mtppy in 1993. The sulfur is now recovered by the Frasch process. About 1.1 million mtppy of powder SSP is produced from two Moritz dens, and 700,000 mtppy of NPKs is also produced.

UBOCZ produces SSP powder and NP and NPK fertilizer blends. Hydrogen fluoride (HF) and silica tetrafluoride (SiF₄) from the SSP plant are recovered as fluorosilicic acid (FSA) and shipped to other fertilizer plants at UBOCZ’s cost.

FOSFORY produces phosphoric acid, sulfuric acid for fertilizers and battery acid, triple superphosphate (TSP), NPK compound fertilizers (4:10:28, 10:9:12, 4:16:18), and sodium silica fluoride.
The Program

The Waste Minimization programs in Poland and Lithuania took place over periods of about 2 years and had the following components:

- Technical assistance.
- Formation of Plant Waste Minimization Committees.
- Training workshops—
  - Waste minimization.
  - Financial calculations.
  - Project controls.
- Study tour including meetings with The Fertilizer Institute (TFI) and the Environmental Protection Agency (EPA).
- Project selection and evaluation.
- Equipment purchase.
- Project implementation and confirmation of benefits.
- Final results seminar.

The Projects

Fifteen projects were completed in the two programs (project descriptions are given in the appendix). The projects in Poland ranged from the typical smaller waste minimization projects like those in Lithuania to much larger projects. Despite the more advanced state of the Polish plants in 1996 compared to Lithuania in 1992, projects could still be found with paybacks of a few months.

A summary of environmental benefits resulting from the 15 waste minimization projects is presented in Table 1.

The participating companies realized significant economic benefits from the waste minimi-

| Table 1. Estimates of Environmental Benefits of Nine Waste Minimization Projects in Poland and Six Projects in Lithuania |
|---|---|---|---|---|
| **AIR** | **Emission Reduction (mtpy)** | | | |
| | Poland | Lithuania | Ammonia | 30 |
| | | | Fluorine | 0.9 |
| | | | SO₂ | 50.6 |
| | | | NOₓ | 3.95 |
| **WATER** | **Discharge Reduction (mtpy)** | | | |
| | Poland | Lithuania | Wastewater (containing fluorine compounds, ammonia and other contaminants) | over 220,000 |
| | | | Fluorine compounds (load) | over 180,000 |
| | | | Solids (load) | over 100,000 |
| | | | Nitrogen compounds (load) | over 10,000 |
| **LAND** | **Disposal Reduction (mtpy)** | | | |
| | Poland | Lithuania | Fluorosilicic acid | 120 |
| | | | Phosphoric acid in phosphogypsum | 489 |
| **ENERGY SAVINGS** | **Energy Savings (GJ / y)** | | | |
| | Poland | Lithuania | 108,000 | 22,000 |
zation projects, as illustrated in Table 2. To implement these projects, WEC contributed about $42,000 for capital investment. Moreover, most of the participating companies adopted the WEC waste minimization and cleaner production philosophy and methodology, investing an additional $524,000 in various waste minimization projects. The total investment of about $566,000 provided total annual savings to the companies of about $868,000.

As shown in Figures 1 and 2, the benefits at the participating companies were achieved largely through activities requiring low-cost investments and short payback periods. This was more so in Lithuania, where all the projects were below $10,000 and all the projects had payback periods of less than 9 months.

As might be expected, it is more likely that smaller projects can be found with shorter payback periods, but some of the larger projects also had good paybacks and intangible benefits (Figure 3). The largest project was the control of an odor problem at POLICE that had the unexpected benefit of improved plant recovery as well as fewer complaints from the plant’s neighbors.

The results of the WEC program provide a compelling financial case for waste minimization and cleaner production. In the final phase of the program, WEC continued the “institutionalization” of waste minimization activities in these and other industry sectors in cooperation with three Pollution Prevention Centers established in the Baltic region. Not only will this strategy achieve environmental and economic benefits in the future, it will also contribute to the restructuring and privatization process of the Lithuanian and Polish fertilizer industry.

### Table 2. Summary of Waste Minimization Projects at Fertilizer Plants

<table>
<thead>
<tr>
<th>Plant Name/Location</th>
<th>Description</th>
<th>Investment US $</th>
<th>Payback Period</th>
<th>Total Savings US $/year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lithuania 1994</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIFOSA, Kédainiai</td>
<td>Better Process Control at MAP Plant</td>
<td>700</td>
<td>0</td>
<td>4,400</td>
</tr>
<tr>
<td></td>
<td>Improved Blowdown from Boilers</td>
<td>900</td>
<td>0</td>
<td>1,700</td>
</tr>
<tr>
<td></td>
<td>Radioactivity Testing</td>
<td>1,100</td>
<td>0</td>
<td>2,600</td>
</tr>
<tr>
<td></td>
<td>Improved DO Monitoring</td>
<td>2,000</td>
<td>0</td>
<td>4,600</td>
</tr>
<tr>
<td></td>
<td>Ultrasonic Leak Detection</td>
<td>5,000</td>
<td>0</td>
<td>7,200</td>
</tr>
<tr>
<td></td>
<td>Combustion Gas Analyzer</td>
<td>10,000</td>
<td>0</td>
<td>22,000</td>
</tr>
<tr>
<td><strong>TOTAL LIFOSA</strong></td>
<td></td>
<td>19,700</td>
<td>0</td>
<td>42,500</td>
</tr>
<tr>
<td><strong>Poland 1998</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LUBON</td>
<td>Condensate Recovery from Polyfos Plant</td>
<td>2,800</td>
<td>600</td>
<td>3,400</td>
</tr>
<tr>
<td></td>
<td>Compaction Granulation Plant</td>
<td>0</td>
<td>95,500</td>
<td>95,550</td>
</tr>
<tr>
<td>FOSFORY, Gdansk</td>
<td>On-line Density Measurement in Sulfuric Acid Plant</td>
<td>6,800</td>
<td>0</td>
<td>101,250</td>
</tr>
<tr>
<td></td>
<td>Improved Filter Feed control in Phosphoric Acid Plant</td>
<td>0</td>
<td>16,800</td>
<td>16,800</td>
</tr>
<tr>
<td></td>
<td>Improved Control in TSP Plant</td>
<td>0</td>
<td>11,250</td>
<td>11,250</td>
</tr>
<tr>
<td>UBOCZ</td>
<td>Recycling of Fluorosilicic Acid in SSP Production</td>
<td>7,000</td>
<td>800</td>
<td>7,800</td>
</tr>
<tr>
<td>POLICE, Szczecin</td>
<td>Reduction in Odors from Phosphoric Acid Plant</td>
<td>0</td>
<td>375,000</td>
<td>375,000</td>
</tr>
<tr>
<td></td>
<td>Use of Mechanical Seals on Evaporator Pumps</td>
<td>0</td>
<td>5,600</td>
<td>5,600</td>
</tr>
<tr>
<td>SIARKOPOL</td>
<td>Wastewater Recycling in NPK</td>
<td>5,500</td>
<td>18,200</td>
<td>23,700</td>
</tr>
<tr>
<td><strong>TOTAL POLAND</strong></td>
<td></td>
<td>22,100</td>
<td>523,750</td>
<td>545,900</td>
</tr>
</tbody>
</table>

**Conclusion**

The results of the WEC program provide a compelling financial case for waste minimization and cleaner production. In the final phase of the program, WEC continued the “institutionalization” of waste minimization activities in these and other industry sectors in cooperation with three Pollution Prevention Centers established in the Baltic region. Not only will this strategy achieve environmental and economic benefits in the future, it will also contribute to the restructuring and privatization process of the Lithuanian and Polish fertilizer industry.
Figure 1. Size of Projects.

Figure 2. Payback of Projects.

Figure 3. Payback of Projects Compared to Project Investment.
Postscript

Since the completion of the Waste Minimization Program in 1994, AB LIFOSA has continued an active waste minimization program and implemented a number of significant measures to reduce pollution. For instance, the following steps were taken to reduce emissions to the atmosphere.

Heat recovered from sulfuric acid cooling systems is being used to heat the company’s premises and for preparation of hot water.

Consumption of fuel oil dropped from 10,761 mt in 1993 to 1,234 mt in 1996. In December 1996 the dryers were changed to use natural gas instead of fuel oil. At the same time, the boiler house was revamped and adapted to use natural gas. The boiler now is operated only when the sulfuric acid plant is shut down. When the sulfuric acid plant is running and generating steam, steam from the boiler is not needed.

A new method of hot air recyle has been introduced at the aluminum fluoride plant. As a result, about 30% of the hot air generated is fed back to the production process. Since the introduction of this measure, releases to the atmosphere have been reduced by 25%. In addition, demand for natural gas used to dry the product has decreased.

In 1998 the company started to use heat recovered from the sulfuric acid cooling systems for Kédainiai City heating. This has reduced emissions from Kédainiai’s power plant in that less fuel is burned.

Fertilizer production increased 2.2 times between 1994 and 1998 while emissions to the atmosphere have remained at the same level or have even gone down (Figure 4).

The following measures were taken to minimize contamination of water with hazardous materials:

- The phosphogypsum stacks and sedimentation pond were revamped. Now, part of the contaminated water from the pond is fed back to production. Thus, a surplus is neutralized in the neutralization station and pumped to the settling ponds. Because, in this way, the water polluted with phosphogypsum could be used in the production process, the company avoided discharging it to rivers/lakes. This measure has reduced phosphate releases to the Obelis River from 62 mtpy to 48 mtpy.
- A new water return line was installed. Through this line ground and rain wastewater passes from a collecting pond to a wastewater circulation system and fluorine circuit for reuse within the plant.
- Automatic control of the production processes is being introduced at the company. This will reduce consumption of power and raw materials and, at the same time, make the absorption process more effective. At present, emission of fluorine compounds from the aluminum fluoride and phosphoric acid plants is in strict compliance with European Commission (EC) guidelines. The company has committed itself to increasing production volumes without an increase in pollutant releases.

In forming its environmental policy, the company has set the following targets:

![Figure 4. Emissions Per Ton of Product.](image-url)
• To bring new projects for public discussions prior to their realization.
• To improve existing production processes and provide them with modern automatic pollution control devices.
• To implement an environmental monitoring system.
• To assess and evaluate plants under construction according to environmental laws and regulations valid in the Lithuanian Republic.
• To modernize the existing processes and plan new ones in accordance with the European Union (EU) criteria and International ISO 14000 standard rates.
• To assign 30% of financial investments to environmental needs.
Appendix—Project Descriptions
Project Descriptions: LIFOSA

Better Process Control at MAP Plant
Company: LIFOSA
Location: Kėdainiai, Lithuania
Year: 1994

<table>
<thead>
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<th>Economic Benefits</th>
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<th>Savings</th>
<th>Payback Period</th>
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<td>700</td>
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<th>Raw Material Savings</th>
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<tr>
<td>Material</td>
<td>Air</td>
<td>Water</td>
</tr>
<tr>
<td>Ammonia</td>
<td>30 mtpy</td>
<td>-</td>
</tr>
</tbody>
</table>

Waste Minimization Project—In the manufacture of monoammonium phosphate (MAP) at LIFOSA, ammonia and phosphoric acid are reacted under controlled pH conditions. Failure to maintain pH at the optimum level results in process upsets and excessive emissions of unabsorbed ammonia into the atmosphere. In the past, pH levels were measured every 20 minutes using pH paper. The accuracy of pH measurements using this method was poor. Therefore, to ensure that the pH levels were sufficient, the reaction was controlled at a higher pH level than necessary. This was accomplished by overformulation of the product, resulting in excess ammonia concentrations in the final MAP product.

During the waste minimization project, methods for obtaining more accurate and timely pH measurements were investigated. It was determined that a laboratory pH meter would provide pH measurements more quickly and accurately than the previous method. Installation of a pH meter has resulted in fewer process upsets and decreased ammonia emissions to the atmosphere. Better process control has also improved process efficiency and reduced the amount of ammonia consumed in the MAP reaction.

Equipment—pH meter; Supplier: Orion, Hillsboro, Oregon.
**Improved Blowdown From Boilers**
Company: LIFOSA  
Location: Kėdainiai, Lithuania  
Year: 1994

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<tbody>
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<td><strong>Investment</strong></td>
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<tr>
<td>USAID (US $)</td>
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<td>Company</td>
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<td><strong>Savings</strong></td>
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<td><strong>Payback Period</strong></td>
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<td></td>
<td><strong>Air</strong></td>
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<td>Fuel oil</td>
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<tr>
<td>Sulfur dioxide</td>
<td>0.6 mtpy</td>
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<tr>
<td>Nitrogen oxides</td>
<td>0.24 mtpy</td>
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**Waste Minimization Project**—The production processes at LIFOSA are supported by a thermoelectric power plant using four oil-fired boilers, each burning 50 mtp of fuel. The boilers generate steam to drive turbines for electricity and also provide steam and hot water for process requirements and domestic use. Oil-fired burners generate soot and carbon, which coat the steam-generating heat exchanger pipes. This in turn reduces the heat transfer between the hot flue gas from the boiler and the steam running through the heat exchanger pipes. Poor heat transfer results in energy losses. To keep the heat exchanger surfaces clean, soot buildup is removed periodically in a procedure called boiler “blowdown.” In the past, the effectiveness of the blowdown was determined by measuring the salinity of the blowdown water in a laboratory. Because the results of this analysis were not immediately available, they could not be used to effectively control the blowdown process and reduce the energy losses occurring due to poor heat transfer in the heat exchanger.

During the waste minimization project, alternative methods for analyzing salinity of the blowdown water were investigated. A decision was made to install a conductivity meter, which could instantaneously measure the water salinity. As a result of the project, frequent measurements of blowdown water salinity are available, allowing boiler operators to clean the heat exchanger effectively and maintain it in good condition. The project resulted in lower fuel consumption and decreased emissions of sulfur dioxide and nitrogen oxides.

**Equipment**—Conductivity/TDS meter CDH-42; Supplier: OMEGA International, Stanford, Connecticut.
**Radioactivity Testing**

Company: LIFOSA  
Location: Kėdainiai, Lithuania  
Year: 1994

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<th>Payback Period</th>
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<td>Air</td>
<td>Water</td>
</tr>
<tr>
<td>Radiation</td>
<td>Yes(^a)</td>
<td>-</td>
</tr>
</tbody>
</table>

\(^a\) Actual estimates not available.

**Waste Minimization Project**—Phosphate rock is imported from Kola in Russia for the production of phosphoric acid. The phosphate rock sometimes contains a higher level of radioactivity than specified. Because customers do not accept finished products that exceed specification, LIFOSA must monitor their raw materials for radioactivity. In the past, the facility sent samples periodically to an outside laboratory for analysis.

During the waste minimization project, methods for more rapid detection of radioactivity in raw materials were evaluated. A decision was made to purchase and use a portable radioactivity meter onsite to screen raw materials for radioactive contamination before they are used in production. The meter can also be used to check and certify that final products are free of radioactivity before shipment to customers. As a result of the project, the plant increased its export sales and improved worker and customer health and safety by reducing exposure to radioactive materials.

**Equipment**—Portable radioactivity meter; Supplier: Technology Associates.
**Improved Dissolved Oxygen (DO) Monitoring**

Company: LIFOSA  
Location: Kėdainiai, Lithuania  
Year: 1994

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<th>Savings</th>
<th>Payback Period</th>
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<td>Water</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>1 mtpy</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>0.4 mtpy</td>
<td>-</td>
<td>-</td>
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**Waste Minimization Project**—The production processes at LIFOSA are supported by a thermoelectric power plant using four oil-fired boilers, each burning 50 mtp of fuel. The boilers generate steam to drive turbines for electricity and also provide steam and hot water for process requirements and domestic use. Water fed to the boiler is pretreated to remove dissolved oxygen. High levels of dissolved oxygen in water cause corrosion and deposits on the inside of the piping in the steam-generating heat exchangers. This in turn reduces the heat transfer between the hot flue gas from the boiler and steam running through the heat exchanger pipes. Poor heat transfer results in energy losses. The deposits were removed manually by maintenance personnel. Pipes and fittings that are severely damaged must be replaced. This process is both expensive and time consuming. Therefore, effective removal of dissolved oxygen from water is critical to extend heat exchanger life, lower maintenance costs, and reduce energy losses from inefficient heat transfer. In the past, dissolved oxygen levels were measured periodically in a laboratory. Because the results of this analysis were not immediately available, they could not be used to effectively control the water treatment process.

Alternative methods for analyzing dissolved oxygen in the boiler feedwater were investigated. A decision was made to install a portable dissolved oxygen meter in the water treatment plant. As a result of the project, frequent measurements of dissolved oxygen are available. Using this information, operators are able to maintain low levels of oxygen in the boiler feedwater. The project resulted in more efficient boiler operation, lower maintenance costs, and decreased fuel consumption.

**Ultrasonic Leak Detection**

Company: LIFOSA  
Location: Kédainiai, Lithuania  
Year: 1994

### Economic Benefits

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<td>Savings</td>
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<td>(US $/year)</td>
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<td>5,000</td>
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### Environmental Benefits

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<td>Air</td>
<td>Water</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>1 mtpy</td>
<td>-</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>0.4 mtpy</td>
<td>-</td>
</tr>
</tbody>
</table>

**Waste Minimization Project**—The production processes at LIFOSA are supported by a thermoelectric power plant using four oil-fired boilers, each burning 50 mtph of fuel. The boilers generate steam to drive turbines for electricity and also provide steam and hot water for process requirements and domestic use. Utilities are distributed to the facility through an extensive network including over 10 km of steam, hot water, vacuum, and air supply lines. Many of these supply lines are old and require continuous maintenance for repair of leaks. In the past, plant personnel conducted visual and audible inspections for leaks and conducted repairs when leaks were detected. However, many leaks went undetected due to inaccessibility of piping and high background noise levels in the process areas. Excessive steam and water losses resulted from undetected leaks in piping. In addition, vacuum and high-pressure air leaks resulted in increased power demand and higher fuel consumption.

During the waste minimization project, alternative methods for leak detection were evaluated. It was determined that an ultrasonic leak detector could quickly locate steam, water, and air leaks from a distance of up to 3 m and could also detect vibrations from bearings that are misaligned or in need of repair. Use of the ultrasonic leak detector not only detects small leaks but also eliminates hazards associated with manual inspections of high-pressure, high-temperature lines. As a result of the project, plant personnel have been able to reduce losses from leaks in utility lines and reduce equipment maintenance costs. In addition, the facility reduced fuel consumption by 52 mtpy and decreased emissions of sulfur dioxide and nitrogen oxides.

**Equipment**—Ultraprobe 2,000 leak detecting system; Supplier: UE Systems, Elmsford, New York.
**Combustion Gas Analyzer**

Company: LIFOSA  
Location: Kėdainiai, Lithuania  
Year: 1994

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<th>Investment</th>
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<tr>
<td>10,000</td>
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<td>10,000</td>
<td>22,000</td>
<td>6 months</td>
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<tr>
<td>Material</td>
<td>Air</td>
<td>Water</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>7 mtpy</td>
<td>-</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>2.9 mtpy</td>
<td>-</td>
</tr>
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</table>

**Waste Minimization Project**—The production processes at LIFOSA are supported by a thermoelectric power plant using four oil-fired boilers, each burning 50 mtph of fuel. The boilers generate steam to drive turbines for electricity and also provide steam and hot water for process requirements and domestic use. The fuel oil burned in the boilers contains as much as 2.5% sulfur. The burners are old and lack the controls necessary to ensure efficient burning of fuel. This results in excessive fuel consumption and significant emissions of sulfur dioxide to the atmosphere.

During the waste minimization project, an investigation was undertaken to improve the efficiency of the boilers. It was determined that a combustion gas analyzer would provide useful information that would enable operators to maintain a more efficient boiler operation. For example, a combustion gas analyzer could be used to measure the oxygen and carbon monoxide in the boiler exhaust on a regular basis. This information in turn could be used by operators to adjust the air/fuel ratio for optimum burning efficiency. To implement the project, a portable stack gas analyzer was purchased and installed. As a result of the project, the facility reduced its fuel consumption by 360 mtpy and decreased emissions of sulfur dioxide and nitrogen oxides.

**Equipment**—Portable stack gas analyzer Model 33; Supplier: Testo Term Co., Flanders, New Jersey.
**Project Descriptions: LUBON**

**Condensate Recovery From Polyfos Plant**
Company: LUBON  
Location: Poland  
Year: 1998

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<th>Payback Period</th>
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<tr>
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<tr>
<td>Material</td>
<td>Air</td>
<td>Water</td>
</tr>
<tr>
<td>Fuel gas</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Water</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wastewater</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>0.4 mtpy</td>
<td>-</td>
</tr>
<tr>
<td>CO</td>
<td>0.029 mtpy</td>
<td>-</td>
</tr>
</tbody>
</table>

**Waste Minimization Project**—Condensate from the heat exchangers in the sodium polyphosphate plant is not recovered. LUBON determined that the condensate could be used in three places:

- For diluting phosphoric acid.
- For washing the cake on the filter.
- For returning to the boiler house.

Implementation of this project required installation of a conductivity meter to monitor the condensate for presence of acid leaks because acidic condensate cannot be returned to the boilers. A steam trap was installed to collect the condensate. An existing stainless steel tank was used for condensate storage, and existing piping was used to return condensate to the boiler house.

**Equipment**—Steam traps and conductivity instruments were selected and purchased by WEC/USAID.
Compaction Granulation Plant
Company: LUBON
Location: Poland
Year: 1998

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<td>USAID (US $)</td>
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<td>95,550</td>
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<tr>
<td></td>
<td>Air</td>
<td>Water</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Fluorides</td>
<td>0.9 mtpy</td>
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<tr>
<td>Sulfur dioxide</td>
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<tr>
<td>Nitrogen oxides</td>
<td>1.7 mtpy</td>
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<tr>
<td>CO</td>
<td>0.2 mtpy</td>
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</tr>
<tr>
<td>Particulates</td>
<td>0.5 mtpy</td>
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</table>

Waste Minimization Project—LUBON is planning to expand its fertilizer production operations by constructing a new production unit to produce granular NPK fertilizer. The NPK fertilizer produced in the new unit will be used initially to increase LUBON’s fertilizer production output. Eventually, the NPK fertilizer may replace the existing SSP fertilizer production for which market demand is less. LUBON plans to use a more environmentally friendly fertilizer process in its new production process for NPK fertilizers. This process will have much lower energy consumption and lower emissions than in conventional processes. The process uses compaction instead of conventional granulation. LUBON intends to test the process in a pilot plant before proceeding with implementing the full-scale plant. LUBON requested assistance from WEC in selection and financing of pilot plant technology and equipment.

Equipment—There was no direct WEC/USAID involvement or funding in this project.
Project Descriptions: FOSFORY

On-Line Density Measurement in Sulfuric Acid Plant
Company: FOSFORY
Location: Gdansk, Poland
Year: 1998

<table>
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<th>Economic Benefits</th>
<th>Investment</th>
<th>USAID (US $)</th>
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<th>Total (US $)</th>
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<th>Payback Period</th>
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<td></td>
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<td>6,800</td>
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<td>18 months</td>
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Environmental Benefits

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<th>Raw Material Savings</th>
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<tr>
<td>Sulfuric acid</td>
<td>Air</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Water</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Land</td>
<td>-</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>40.2 mtpy</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
</tr>
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**Waste Minimization Project**—The sulfuric acid plant at FOSFORY is a large emitter of SO₂. There was no continuous density measurement or on-line SO₂ monitoring capability at this or any other plant at FOSFORY. On-line density monitors can be used to improve control in the sulfuric acid plant. A portable SO₂ analyzer was used to improve process control at various points throughout the plant and reduce SO₂ emissions.

**Equipment**—A portable SO₂ analyzer was specified and purchased by WEC/USAID.
Improved Filter Control in Phosphoric Acid Plant
Company: FOSFORY
Location: Gdansk, Poland
Year: 1998

### Economic Benefits

<table>
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<tr>
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<td>0</td>
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### Environmental Benefits

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<td>Phosphoric acid</td>
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<tr>
<td></td>
<td>Air</td>
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<tr>
<td></td>
<td>Water</td>
<td>239 mtpy</td>
</tr>
<tr>
<td></td>
<td>Land</td>
<td>-</td>
</tr>
</tbody>
</table>

**Waste Minimization Project**—The feed to the filter in the phosphoric acid plant was controlled by a constant head box with an adjustable plug outlet. This method is crude and does not allow operators to achieve optimum process control. An improved method of control would be to use a variable speed pump regulated by the flow measured by a magnetic flowmeter.

FOSFORY calculated benefits of over $19,000 a year for this project and decided to install the system using their own funds.

**Equipment**—A magnetic flowmeter and variable speed drive were specified by WEC/USAID.
**Improved Control in TSP Plant**  
Company: FOSFORY  
Location: Gdansk, Poland  
Year: 1998

### Economic Benefits

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<tbody>
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<td>Company</td>
<td>Total</td>
<td>Savings</td>
</tr>
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<td>(US $/year)</td>
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<td></td>
</tr>
<tr>
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<td>11,250</td>
<td>11,250</td>
<td>26,400</td>
</tr>
</tbody>
</table>

### Environmental Benefits

<table>
<thead>
<tr>
<th>Material</th>
<th>Reductions in Environmental Releases</th>
<th>Raw Material Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Air</td>
<td>Water</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Electricity</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>4.4 mtpy</td>
<td>-</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>0.85 mtpy</td>
<td>-</td>
</tr>
<tr>
<td>CO</td>
<td>0.015 mtpy</td>
<td>-</td>
</tr>
<tr>
<td>Particulate</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Waste Minimization Project**—The feed from the reactor to the granulator in the TSP plant was controlled by a manual control valve. This method is crude and does not allow operators to achieve optimum process control. An improved method of control would be to use a variable speed pump regulated by the flow measured by a magnetic flowmeter.

FOSFORY calculated benefits of over $26,000 a year for this project and decided to install the system using their own funds.

**Equipment**—A magnetic flowmeter and variable-speed drive were specified by WEC/USAID.
Project Descriptions: UBOCZ

Recycling of Fluorosilicic Acid in SSP Production
Company: UBOCZ
Location: Poland
Year: 1998

<table>
<thead>
<tr>
<th>Economic Benefits</th>
<th>Investment</th>
<th>Savings (US $/year)</th>
<th>Payback Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>USAID</td>
<td>Company</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>7,000 (US $)</td>
<td>800</td>
<td>7,800</td>
<td>22,500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental Benefits</th>
<th>Reductions in Environmental Releases</th>
<th>Raw Material Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Air</td>
<td>Water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>360 mtpy</td>
</tr>
<tr>
<td>FSA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Waste Minimization Project—SSP is manufactured from phosphate rock and sulfuric acid. The process produces fluorides that were recovered as fluorosilicic acid (FSA) and sent to another fertilizer producer in Poland by rail. UBOCZ had to pay for transport and maintenance costs and would have had to reline an FSA storage tank the next year. UBOCZ received no income for this waste product. As well as saving the costs of transporting FSA, this project would reduce the amount of sulfuric acid consumed. To implement this project, UBOCZ would need a system capable of accurately feeding FSA to the SSP plant.

UBOCZ confirmed the process concept in lab tests and determined that an acceptable product could be made.

Equipment—Metering pump, magnetic flowmeter, control valve, and spray nozzle were specified and purchased by WEC/USAID.
Project Descriptions: POLICE

Reduction in Odors From Phosphoric Acid Plant
Company: POLICE
Location: Szczecin, Poland
Year: 1998

<table>
<thead>
<tr>
<th>Economic Benefits</th>
<th>Investment</th>
<th>Savings</th>
<th>Payback Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>USAID Company</td>
<td>0</td>
<td>375,000</td>
<td>562,500</td>
</tr>
<tr>
<td>Total (US $)</td>
<td>375,000</td>
<td></td>
<td>8 months</td>
</tr>
<tr>
<td>(US $/year)</td>
<td>375,000</td>
<td>562,500</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental Benefits</th>
<th>Reductions in Environmental Releases</th>
<th>Raw Material Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Air</td>
<td>Water</td>
</tr>
<tr>
<td>Phosphate rock</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(in gypsum)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Waste Minimization Project**—In the phosphoric acid plant, phosphate rock is reacted with sulfuric acid to produce phosphoric acid and gypsum. Fumes containing hydrogen fluoride (HF) and silicon tetrafluoride (SiF₄) are released and must be captured and scrubbed. Minute traces of other compounds are present and may cause "nuisance" emissions, being in some cases below detectable limits.

WEC provided technical assistance to POLICE to help solve this problem. POLICE subsequently installed an ozonation system to inject ozone into the reactor slurry in the phosphoric acid plant reactor.

POLICE worked with the Technical University of Szczecin to measure the odors. Gas samples taken at the plant were smelled by a group of student and diluted to 50% and smelled again. This procedure was then repeated to get a qualitative measurement of the odors.

POLICE also worked with an institute in Gliwice to evaluate the effect of ozonation on the phosphoric acid process—particularly the effect on gypsum crystallization. It was found that larger gypsum crystals are produced. This has led to improved filter wash efficiency and hence less phosphoric acid discharged with the gypsum waste and lower phosphate rock consumption.

**Equipment**—Ozonation system supplied by OZONIA.
Use of Mechanical Seals on Evaporator Pumps
Company: POLICE
Location: Szczecin, Poland
Year: 1998

<table>
<thead>
<tr>
<th>Economic Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
</tr>
<tr>
<td>USAID (US $)</td>
</tr>
<tr>
<td>Company (US $)</td>
</tr>
<tr>
<td>Total (US $/year)</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>5,600</td>
</tr>
<tr>
<td>5,600</td>
</tr>
<tr>
<td>13,500</td>
</tr>
<tr>
<td>5 months</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
</tr>
<tr>
<td>Reductions in Environmental Releases</td>
</tr>
<tr>
<td>Air</td>
</tr>
<tr>
<td>Coal</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
</tr>
<tr>
<td>CO</td>
</tr>
<tr>
<td>Particulates</td>
</tr>
</tbody>
</table>

**Waste Minimization Project**—Phosphoric acid is concentrated from filter strength (27% P$_2$O$_5$) to the strength required for fertilizer production (42% to 52% P$_2$O$_5$) in forced circulation evaporator units. About 1.25 mt of steam is used per metric ton of water evaporated. However, when pumps with conventional packing are used in the system, seal water must be used. A large portion of this seal water enters the phosphoric acid. Depending on the type of pump and packing, the additional water can be several cubic meters per hour and can increase steam consumption by as much as 25%. If it is possible to use a mechanical seal on the pump, seal water is eliminated and steam can be saved.

POLICE decided not to install mechanical seals because the pumps would have required modification. Instead a seal water control system was installed. This controlled the flow of seal water accurately and shut off the water when the pump stopped. The cost of the installation was less than the cost of mechanical seals and the savings slightly lower. The payback was in the same range as that for the original project.
**Project Descriptions: SIARKOPOL**

**Wastewater Recycling in NPK Plant**
Company: SIARKOPOL  
Location: Poland  
Year: 1998

<table>
<thead>
<tr>
<th>Economic Benefits</th>
<th>Investment</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>USAID</td>
<td>Company</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>(US $)</td>
<td>(US $/year)</td>
<td></td>
</tr>
<tr>
<td>5,500</td>
<td>18,200</td>
<td>23,700</td>
<td>24,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12 months</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental Benefits</th>
<th>Reductions in Environmental Releases</th>
<th>Raw Material Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Air</td>
<td>Water</td>
</tr>
<tr>
<td>SSP</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NaOH</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NaCl</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>H₂SiF₆</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fluorides</td>
<td>-</td>
<td>80 mtpy</td>
</tr>
<tr>
<td>N compounds</td>
<td>-</td>
<td>20 mtpy</td>
</tr>
</tbody>
</table>

**Waste Minimization Project** — The NPK granulation plant produced 30 to 40 m³/h of wastewater from the scrubbers. To avoid lime treatment it would be desirable to produce a more concentrated waste stream and recycle it within the plant. Although air emissions currently meet permitted levels, it is unlikely that they will if the quantity of wastewater is reduced and the concentration of fluorides in the wastewater is increased.

The environmental regulators intended to shut this plant down if SIARKOPOL did not reduce the fluorine load in their wastewater. The option of adding a wastewater treatment plant was initially considered, but this would have cost over US $1 million. This “end-of-pipe” solution would not have returned any economic benefits (apart from avoiding the plant being shut down!).

By improving process control, SIARKOPOL can now consume the waste from the scrubbers in the NPK plant and generate raw materials savings.

**Equipment** — A pump, spray nozzles, and pH meter were specified and purchased by WEC/USAID.
Acknowledgments

The Waste Minimization Program was implemented by WEC under a grant from USAID.

Project Descriptions for the Lithuanian projects were taken from "Economic and Environmental Benefits of Industrial Waste Minimization in Estonia, Latvia and Lithuania," WEC 1995.

The authors wish to thank Radoslaw Obermajer from the Pollution Prevention Center, Opole, Poland, for his contributions both to this article and to the work in Poland.
Pollution Prevention and Resource Management: Phosphate Fertilizer Production in the United States

Edgar O. (Ozzie) Morris
Cargill Fertilizer, Inc.
U.S.A.

Introduction

Pollution prevention and resource management are part of the strategy of Cargill Fertilizer, Inc., in operating its facilities. This strategy is based on reducing operational costs, reducing risk, and improving public perception. A measurement program is in place that tracks the progress of these efforts. Successful results have been achieved in water use, phosphate losses, hazardous waste generation, waste minimization, and toxic releases. Additional opportunities are possible through better management, better technology, and government incentives worldwide.

Who Are Cargill and Cargill Fertilizer?

Cargill has deep roots in agriculture. Since its founding in 1865 as a grain trading company, it has become one of the world’s largest privately owned companies. Today, Cargill operates a broad range of agricultural and food businesses worldwide that utilize its knowledge and skills in processing, trading, transportation, and distribution. Agriculture remains a key focus, and the company’s 70,000 employees in 58 countries are dedicated to offering customers high-quality products and services.

Cargill’s agricultural experience provides a valuable resource for Cargill Fertilizer customers. Whether it is developing improved products, incorporating best practices into its own and customers’ businesses, ensuring the most reliable delivery, or providing the most competitive prices, Cargill’s agricultural expertise produces added value for the customer.

The company’s mission is to be the best at delivering competitively priced, high-quality fertilizers and crop-protection products to farms and farm retailers worldwide, and to do so in environmentally responsible ways.

The focus on helping customers realize bigger harvests and greater profitability is a practical reflection of Cargill’s corporate vision of improving the standard of living wherever it does business. Raising living standards starts by expanding food supplies. Crop yields must increase if there is to be enough food for the Earth’s projected population of 6 billion people by the year 2000 and beyond. Fertilizer is essential to meeting the world’s food needs.

To achieve its mission, Cargill is a single source for a wide range of products and vertically integrated distribution services that is unprecedented in the fertilizer industry. Each of these services is a link in the chain of commitment to serving customers’ needs. Benefits include (1) phosphate, ammonia, and urea fertilizers manufactured to exacting standards; (2) worldwide trading and marketing capabilities complemented by a unique international transportation and distribution network; (3) wholesale and retail marketing-support services; (4) crop-protection products; (5) a broad range of agronomic advice and application services; and (6) recordkeeping programs for farm customers.

Cargill Fertilizer Division is one of the world’s largest producers of phosphate and nitrogen fertilizers. Two plants in Florida produce phosphate fertilizers, while the Canadian joint-venture plant in Saskatchewan manufactures nitrogen fertilizers. The three plants produce approximately 5 million mt of fertilizers annually.

Cargill Fertilizer has earned a reputation for the quality and consistency of its products and services. Our commitment to quality begins by training every employee in the Total Quality Process. From that training has come our dedication to consistent phosphate and nitrogen granule size—which promotes accurate bulk blending and uniform application in the field—and the hardness and dust-free characteristics that minimize degradation and shrinkage during handling and shipping.
In the past 8 years, Cargill Fertilizer has invested over $400 million in technologies that assist in maintaining plants, improving efficiencies, ensuring employee safety, and safeguarding the environment.

Why Pollution Prevention and Resource Management?

In 1990, the United States Congress passed the Pollution Prevention Act; rather than focusing primarily on waste management, this action embraced source reduction as national environmental policy. Under the law, companies are required to have pollution programs for waste that is classified as hazardous. They are also required to report releases to the Environmental Protection Agency (EPA) and to provide documentation of procedures to be implemented to reuse these materials or prevent their release. The act emphasizes that pollution can best be achieved by reducing emissions at the source and providing for recycling of raw materials, whenever economically possible, of those materials that can be safely used. Treatment and disposal are to be viewed as last-resort measures.

Pollution Prevention and Resource Management are gaining recognition as major methods of dealing with hazardous waste problems and other forms of pollution. The problems and cost associated with waste disposal are reasons for implementing source reduction activities. Environmental regulations have been the fastest growing incentive in recent years for source reduction activities. Other factors include waste disposal cost, product output (operating cost, yield improvements, quality, and customer specifications), and liability (worker safety and community relations).

There are several reasons for businesses to initiate a pollution prevention program. A company with an aggressive program may well be the lowest cost producer and gain a significant edge over its competitors. The incentives may include the following.

Economics
Attractive economics in waste management and disposal costs and material savings are a result of an effective pollution prevention program. A good program will yield cost savings because of improvements in yields, optimum utilization of raw materials, and lower energy costs. Lower quantities of regulated hazardous waste will be generated, thereby minimizing waste management and compliance cost. The cost per unit produced will decrease as operating costs are lowered. The cost of the program's development and implementation can be more than offset by savings.

Regulations
Regulatory incentives include current and future regulations restricting air, aqueous, and solid waste (including hazardous) discharges from facilities. These regulations include new federal and state regulations mandating pollution prevention plans for various types of facilities.

Reduced Liability
Under the Federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), companies are subject to the possibility of unlimited liability for any harm caused by their waste. The liability includes even future problems caused by wastes currently managed using the best practices. According to Standard and Poor's report, "environmental liabilities of U.S. corporations now exceed $100 billion." In an NBC and Wall Street Journal poll, 4% of the American public believe that damaging the environment is a serious crime, and 75% think that corporate executives should be personally liable for these offenses.

Environmental Benefits
Environmental incentives include the desire to provide a clean environment.

Public Perception
According to a Chemical Manufacturing Association report on pollution prevention, the American public ranks the chemical industry 10th among 11 industries, just above tobacco and below nuclear power industries. Public relations incentives revolve around increased public sentiments for reducing the discharge of emissions into the environment. Pollution prevention activities are viewed favorably by the public in this era of "Community Right To Know" laws. Company image is improved by established policies, practices, and commitment to waste reduction.

Water Conservation
Florida phosphate mining and processing require large volumes of water. The Florida phosphate industry, however, is well aware of the need to conserve this valuable resource. For the industry as a whole, about 95.4% of the water needed in the mining process is reused. This is done through water conservation areas that recover, store, and recirculate the water. In the manufacturing processes, 92.1% of the water used is also captured and recycled.

1. Citation of unpublished material
To further reduce the industry’s need for groundwater and to assist local governments, some facilities utilize treated domestic wastewater as part of the makeup water needed to operate. In 1998, use of this water by industry allowed local governments to dispose of more than 3.1 million gallons of treated wastewater each day. An additional 8 million gallons of treated wastewater was used daily for cooling water and returned to the wastewater facility for reuse, thus further conserving precious groundwater resources. The progress made in better water management and recycling of wastewater is clearly shown in Table 1.

Cargill Fertilizer’s chemical facilities have minimized the use of freshwater through an extensive system allowing continued reuse of water as the quality degrades to different levels. An effort of this type requires the resources of engineering and management time and capital input. Future freshwater input will be replaced over time by local municipal wastewater. In addition, the ammonia-neutralized process water is used for the grinding of phosphate rock, and the phosphate and nitrogen content is recovered in the production of ammoniated products.

### Hazardous Waste Management

Cargill Fertilizer has initiated a program aimed at the reduction of hazardous wastes generated by its operations in both fertilizer manufacturing and mining. Methods of reduction include (1) elimination of the process generating the waste, (2) neutralization and recycle of wastes back into product streams, and (3) use of nonhazardous products or materials instead of products or materials that cause generation of hazardous wastes.

An example of the first reduction method deals with paint-related wastes. Cargill has made the decision to have on-site painting done by contractors. This has eliminated the need to store and use hazardous paint thinners and cleaners such as xylene and methyl ethyl ketone, as well as waste paint that can be hazardous. In addition, assistance is given to contractors to ensure the materials brought on site are handled correctly and do not create waste problems.

Laboratory wastes that are acid based can be returned to the process for recovery of P₂O₅ value instead of being collected for handling off site. Alternately, wastes that are characteristically hazardous due only to a low pH can be neutralized and recycled. Both methods eliminate the need to record and report the wastes, and neutralization also reduces the hazard of handling acid wastes.

Examples of product substitution include (1) citrus-based cleaners instead of mineral spirits, (2) nonignitable parts washer solvents, (3) nonchlorinated products in vehicle maintenance items (such as brake cleaners), and (4) systematic replacement of PCB-containing electrical equipment.

The largest reduction in the volume of hazardous wastes generated has been due to the use of nonhazardous greases for lubrication on the draglines at the mines. In the past, some of the heavy greases used on the large machines contained either lead or chlorinated solvents. These additives enhanced performance of the grease but caused all associated wastes to be classified as hazardous due to toxicity. Operations, maintenance, and environmental staff worked with vendors and suppliers to obtain acceptable substitutes. Figure 1 is a graph showing reductions in hazardous waste amounts from mining operations.

New opportunities to reduce wastes are continuously being sought. Review of Material Safety Data Sheets (MSDSs) by the environmental staff is required for any new products prior to them being considered for use. Additionally, annual testing of regular waste streams ensures that a hazardous waste is not inadvertently being generated. As a result of these steps, all Cargill Fertilizer facilities are either small-quantity or conditionally exempt generators with total elimination of hazardous wastes as the goal.

<table>
<thead>
<tr>
<th>Year</th>
<th>Mining Water Pumped (gal/day)</th>
<th>Rock Produced (MMT)</th>
<th>Gallons of Water Per Ton of Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>117,485,900</td>
<td>36.2</td>
<td>1,185</td>
</tr>
<tr>
<td>1992</td>
<td>88,417,600</td>
<td>36.2</td>
<td>892</td>
</tr>
<tr>
<td>1993</td>
<td>64,535,036</td>
<td>25.2</td>
<td>935</td>
</tr>
<tr>
<td>1994</td>
<td>62,405,789</td>
<td>29.1</td>
<td>785</td>
</tr>
<tr>
<td>1995</td>
<td>50,125,000</td>
<td>33.8</td>
<td>541</td>
</tr>
<tr>
<td>1996</td>
<td>56,034,000</td>
<td>36.2</td>
<td>565</td>
</tr>
<tr>
<td>1997</td>
<td>56,843,000</td>
<td>32.8</td>
<td>633</td>
</tr>
<tr>
<td>1998</td>
<td>53,660,900</td>
<td>34.1</td>
<td>576</td>
</tr>
</tbody>
</table>

Source: Florida Phosphate Council Industry Data.
Cargill Fertilizer, Inc. has been tracking wastes generated since they began operations in Florida. The original thought was to track the amount of solid waste going to the county landfill, hazardous waste being incinerated, air emissions, water discharges, and nonhazardous waste being treated and disposed of. The short-term benefits of waste reduction were immediate cost savings and liability reductions; long-term global issues included a reduced volume entering landfills from Cargill Fertilizer.

During the succeeding years, as process improvements were implemented and the plant size was nearly doubled, Cargill Fertilizer realized that tracking waste numbers by “total” was not the best method for identifying waste reductions. It was decided that the “waste generation efficiency” needed to be improved: i.e., ratio of the pounds of waste per ton of product (analogous to miles per gallon).

Beginning in FY 1996 (Cargill’s fiscal year starts June 1 so FY 1996 is June 1, 1995-May 31, 1996), Cargill Fertilizer instituted a formal goal of a 30% waste ratio reduction by FY 2000. Another way to think of this goal is that the Cargill Fertilizer’s waste efficiency needs to improve by 30%. The FY 1996 ratio was 1.91 and the FY 1998 ratio 1.59, corresponding to a 16.6% reduction since the goal was instituted.

Since establishing the waste minimization goal, Cargill Fertilizer has (1) all but eliminated hazardous wastes, (2) recycled more waste streams, (3) reduced the SO₂ emission limits from 4 lb/ton to 3.5 lb/ton, and (4) lowered freshwater use by using stored water or reclaimed water.

At the midpoint on the way to FY 2000, more than one-half of the goal has been reached (Figure 2). Cargill Fertilizer plans to reduce the ratio to at least 1.33 in FY 2000, which will meet the overall goal of 30% reduction.

**Toxic Release Inventory**

The Toxic Release Inventory (TRI) is an annual report of toxic chemical pollution released into the environment by businesses throughout the country. This reporting requirement was imposed so that EPA, other levels of government, and the public can analyze industry’s progress toward reducing pollution.

The requirement for this report stems from the accidental toxic gas release from a Union Carbide chemical plant in Bhopal, India, in 1984. In 1986, Congress passed the Emergency Planning and Community Right-to-Know Act (EPCRA) making release reporting mandatory. Under EPCRA’s Section 313, specific manufacturing facilities must annually report on their toxic releases into the air, land, and water.

The TRI information is not designed to show if chemical releases pose potential health or environmental hazards. Rather,
the reports simply divulge how many pounds of chemicals companies release, dispose of, treat, and recycle. TRI is intended to help communities with emergency planning. More importantly, TRI acts as a tool that communities can use to discover types and amounts of toxic chemicals released in or near their neighborhoods. If citizens object to chemical releases in their area, they can pressure facilities to use pollution prevention and source reduction techniques to decrease releases. The rule requires more than 31,000 facilities to publicly report their toxic emissions.

Cargill Fertilizer reports annual TRI releases for phosphoric acid, ammonia, sulfuric acid, and hydrogen fluoride; the total amounts released are shown in Figure 3. Since reporting began in 1987, releases have been reduced by over 86%. In 1987 total releases of 7.4 million pounds were reported. By 1997, this amount had been reduced to 1.0 million pounds. It should be noted that two-thirds of the release amount currently reported is dilute phosphoric acid contained in process water used in the fertilizer manufacturing process. This reported release is an estimate based on seepage of the water from the process to the ground. There is no evidence from groundwater monitoring wells that this material is actually released from the facility. The improvements achieved by Cargill have resulted from significant facility upgrades. These include the closure of an unlined phosphogypsum stack, installation of an extensive slurry wall containment system, construction of a new lined phosphogypsum stack, installation of a flare for combustion of ammonia emissions, and elimination of the use of gaseous chlorine. It is also important to note that the 86% reduction in total emissions was accomplished at the same time that total production was increased by over 40%.

Cogeneration

Maximum, efficient use of cogeneration is an optimal pollution prevention and resource management effort for a phosphate fertilizer facility. Cogeneration improvements can offset power generated from fossil fuel, thereby reducing sulfur dioxide emissions that are community health concerns and greenhouse gas emissions that are a major global concern.

Projects that reduce the levels of SO2 emitted into the atmosphere are extremely beneficial to the community as a whole. Cargill is presently expanding one of the sulfuric acid plants in Riverview, Florida. The expansion will allow a reduction in the SO2 limit from 4 lb/ton down to 3.5 lb/ton, which is among the lowest in the industry. Although operating the plants with lower SO2 emissions levels is helpful in reducing the ambient concentration of this pollutant, the increase in energy production will have a greater impact on the community. The expansion of this plant will increase the facility’s power production capability from 41 MW to 70 MW, drastically reducing the amount of power the facility imports.

More than 90% of the SO2 emitted in the area is generated from coal-powered utilities. The displacement of power generation from the utilities to the Cargill Riverview facility will reduce the amount of SO2 emitted by as much as 2,200 stpy from this project alone, thereby providing a cleaner community. The benefits of the cogeneration project on greenhouse gas emissions are also significant. The additional power that is provided by cogeneration rather than coal combustion by utility companies will reduce CO2 emissions by 300,000 stpy. Total reduction in CO2 emissions from operation of Cargill’s chemical plants in Bartow and Riverview, Florida, will be about 1.4 million stpy of CO2.

Summary

Cargill Fertilizer is committed to pollution prevention and resource management. This approach makes sense for our business and our community worldwide. We see continued improvement opportunities in water management, improved product recovery, waste minimization, cogeneration, and emission reduction. Cargill has set a goal of 30% reduction in waste production every 5 years. In Cargill Fertilizer’s view, waste minimization also includes improved resource management.
Introduction

With this workshop being dedicated to fertilizers and the environment, one could not avoid mentioning the European Union (EU) Integrated Pollution Prevention and Control (IPPC) Directive 96/61/EC. This Directive, however, is a significant departure from the original philosophy of the Treaty of Rome (Treaty), which intended initially to build a common market based on free circulation of products between its members. Enlargement has brought in some new axes of action, one of which is protection of the environment in the broad sense. An example of this change is the article of the Treaty on which the Directive is based. The “Fertiliser Directive” 76/116/EC is based on article 100A, which calls for the free circulation of goods by elimination of barriers to trade, whereas the IPPC Directive is based on article 130S, which calls for high protection of the environment and has practically nothing to do with the circulation of goods other than ensuring that there is a certain degree of uniformity in the way pollution issues are handled.

This paper will attempt to explain what the IPPC Directive is all about, what the main points are, and how the whole matter is being and will be handled by the EU Commission and the Member States. This paper will also highlight the possible influence of the fertilizer industry in the process.

IPPC Directive

First of all it should be stated that the IPPC Directive is an EU Council Directive, which means that it is the highest type of law the EU can promulgate and that it is based on article 130S of the Treaty. There is no provision for the EU Commission to alter or modify the IPPC Directive by an EU Commission Directive other than that included in article 19 pertaining to the EU “Committee” procedure regarding article 15§3 concerning the inventory of main emissions and sources. All other modifications must go through the procedure of an EU Council Directive, which involves discussions and acceptance not only by Members States but also by the Parliament. The main points of the Directive are as follows.

Implementation/Application

It is to be implemented in national laws by October 30, 1999, and be applied by the same date for new installations and by October 2007 for existing installations.

Scope of Application

It covers all industrial activities spelled out in an annex as far as the integration of pollution prevention and control is concerned, with the aim of attaining a high level of protection of the environment. These activities are mentioned under headings as follows: energy production, metals transformations, mineral industries, chemical industry, and waste management. Mining industries and nuclear energy are not mentioned, and installations for research, development, and experimentation of new products and processes are specifically excluded. The Directive also includes an indicative list (in Annex III) of emitted substances with respect to emissions to air and water. Curiously, the soil compartment has been left out despite the fact that the Directive deals with landfills.

Authorization/License to Produce

This is the cornerstone of the Directive. The competent Member State authorities are in charge of issuing authorizations to operate any industrial installation, or part of it, falling within the scope of the Directive, on the basis of compliance with environmental rules spelled out by the IPPC Directive. In other words, Member State authorities are in charge of issuing “operating permits.”

The compliance is judged against Community Emission Limit Values (ELV) and Environmental Quality Standards (EQS). Emission Limit Values will be based on information gathered through the Information Exchange Forum (IEF) and pub-
lished in process-related Best Available Techniques Reference Documents (BREFs), the basis of the latter being Best Available Techniques (BAT). I insist on the word Techniques, which in the context of the IPPC Directive is not only Technology but much more (as discussed below).

The process of authorization is organized in a relatively transparent manner where the general public, nongovernmental organizations (NGOs), and others have access to the information provided as the basis of the request for authorization and can express their approval or concern. It is usually at this stage that any project can be scuttled by forceful vocal minorities. Industry management should plan public relations very carefully to avoid this.

Emission monitoring is prone to analytical imprecision and not perfectly stable plant operations: therefore, when discussing an authorization with the competent local body, industry should also insist that it be allowed to operate under a set range for emission values rather than under a single strict cut-off limit. There are different ways of accomplishing this, either by allowing fluctuation within a reasonable range or by allowing a time-limited override of the emission value.

**New/Existing Units**

A distinction is made in the Directive between existing units and units that will be built after the application of the Directive. This has been done at the insistence of industry because in some cases there is no possibility for existing units to be brought to par with new units incorporating the latest techniques with respect to the environment nor is it possible to immediately bring in techniques that will conform to the latest BAT emission levels for existing units. There is a time allowance of 8 years to implement the Directive in full for existing units.

**Emission Limit Values and Environmental Quality Standards**

There is a definition of what is meant by ELV in article 2§6 but no means of how they are obtained. On the other hand, article 9§4 says clearly that ELV are based on BAT but nothing else about the determination of Community Emission Limit Values which, as per article 18, will be set by the EU Council acting on a proposal of the EU Commission. There appears to be no possibility of direct input from bodies other than the EU Commission staff to influence the proposal made by the EU Commission. Therefore, the starting point is the BAT. The next section of this paper will discuss how the whole matter is organized by the EU Commission with an eye on the “transparency of information.”

As far as the issue of EQS is concerned, I am surprised. There is a definition of that item in the Directive: the Directive says also that EQS may lead to requirements more stringent than emission levels attained by BAT, but there is strictly nothing about how these EQS are elaborated. It follows that an operating permit may depend on an item, the elaboration of which is unknown, and may have to follow requirements on emissions more stringent than those that can be obtained by the use of BAT. How can this be achieved? I have no comment on this issue.

Industry should watch the development of EQS very carefully and should also pay attention to other fields because it may well happen that EQS elaborated for a completely different set of regulations may “spill over” to the IPPC Directive with devastating effects. One issue I am particularly thinking of is transboundary pollution.

**BAT Reference Documents--BREFs**

The EU has already prepared BAT documents for water, based on directive 76/464/EC where T in BAT means “technology,” and for air as with directive 84/360/EC where “BAT” is in fact “best available technology not entailing excessive cost.”

United Nations Economic Commission for Europe (UN/ECE) has prepared documents on abatement technologies to be used as BAT documents.

The Oslo-Paris Convention Commission (OSPARCOM) has prepared BAT documents primarily on water aspects, which could, in the future, become legally binding to member parties.

The European Fertiliser Manufacturers’ Association (EFMA) has published a series of eight BAT booklets covering practically all aspects of fertilizer manufacture in Western Europe. These booklets are based on the definition of BAT given by the IPPC Directive and, in fact, in response to the Directive, where the T stands for “techniques” and not for “technology.”

Whereas there is not much contention as to what “best” means in a BAT, the discussion may start with “available” and will surely involve the letter T because there is the current misunderstanding concerning technology and techniques. The IPPC Directive has the merit of settling these issues by giving clear definitions. The important point here is that the term “techniques” includes technology, operation, maintenance, and even decommissioning, while “available” means existing and proven on industrial scale under viable economic conditions. It has nothing to do with some proposals based on unproven “back-of-envelope technology” ideas.
Any existing documents could, in theory, be applied by the permitting authority in that they have only a guiding character. However, the EU Commission has been entrusted, through article 16§2 of the Directive, with establishing an Information Exchange Forum, which, in practice, will endorse compilations of BAT Reference Documents, the so-called BREFs. IEF is composed of representatives of Member States, Directorate General (DG) XI, observers from industry via the Union of Industrial and Employers’ Confederations of Europe (UNICE), and NGOs via the European Environmental Bureau (EEB).

The Commission itself does not have the necessary expertise to establish BREFs, so it has created the European IPPC Bureau (EIPPCB) which handles the contract made with the EU Institute for Prospective Technological Studies (IPTS) in Seville. IPTS has the charge of elaborating BREFs by bringing together experts and information pertinent to various sectors for which BREFs are necessary. The actual drafting of a BREF will be done by a Bureau expert supported by a Technical Working Group (TWG) comprising approximately 15 Member States experts, 5 to 10 industry experts, and 1 to 2 experts nominated by environmental NGOs. The TWG has the following responsibilities:

- Provide up-to-date information in advance of the work.
- Participate in and contribute to the two official meetings of the TWG.
- Respond to any questions of the IPPC Bureau expert.
- Exchange all relevant information.
- Review the BREF twice.

It will then be up to DG XI to formally adopt the REF after a final IEF discussion.

![Figure 1. BREF Information Flow.](image-url)
European Chemical Industry Council (CEFIC) Involvement

As far as chemicals are concerned, and this includes fertilizers, CEFIC has decided to coordinate industry efforts by setting up a CEFIC Task Force BAT (TF BAT), which is in charge of managing the process from the industry side and mainly getting all the preparatory work done before the official “kick-off” meeting in Seville for each BREF. This process involves in particular:

- Identification of the concerned sector groups and associations and establishment of shadow groups.
- Identification of experts for the TWG from shadow groups.
- Information flow management between outside experts and TF BAT.
- Compilation of information for the Bureau expert for a specific BREF.
- Preparation of “drafts” for each of the seven chapters of a BREF with a general part and specific paragraphs for relevant products or product groups.
- Nomination of the industry experts for the TWG.

The most important points here are the compilation of information and the preparation of “drafts” that will be proposed by CEFIC to each TWG. It must be borne in mind that this is the only way industry can make its expertise known: by providing the “hands-on” type of expertise and knowledge that are simply not available elsewhere. We also know that industry is not the only possible contributor to the information exchange process and building of a BREF. Some Member States have already established their own national BREFs, which they will submit to the TWG, and there are various organizations that would like to influence the whole process as well. It is therefore up to the chemical industry as a whole to provide the most sensible and trustworthy information, in order to avoid getting squeezed out of existence by some wishful thinking.

All companies have been called to contribute to this huge task, and experience shows that most do this quite willingly. Some have even taken the lead through their associations. As an example, I would now like to single out the work that has been done in the fertilizer area by EFMA.

EFMA Involvement

EFMA enhances information flow among members while allowing them to make decisions on points of common interest quite fast when needed. The IPPC Directive is a case in point. We knew about EU draft proposals for the IPPC Directive, and the EFMA Technical Committee debated the implications for our industry well before the IPPC Directive was in the final draft stage before the EU Council. It was decided that the best stance we could take was a proactive one consisting of drafting our own internal BATs, agreed on by all the members. The proposal also was to do this work as fast as possible, on a crash program through an ad hoc task force, and officially publish our entire work. The EFMA Steering Committee accepted the proposal, and within 18 months we succeeded in publishing, in 1995, a series of eight BAT booklets covering practically all fertilizer processes, including those for starting materials and intermediates. The BAT booklets were endorsed by the International Fertilizer Industry Association (IFA), and thus they were spread worldwide among IFA members. This was well ahead of the official publication of the IPPC Directive, which occurred in the second half of 1996.

After publication of the IPPC Directive, EFMA gave the BAT booklets to the EU Commission, in fact to DG XI, where they were very well received, and through EFMA members these booklets have also been forwarded to all national authorities.

EFMA has also participated actively in the elaboration of the Ammonia BREF by delegating experts to the TWG, which handled the work in Seville. The Ammonia BREF was finalized, but because there was a switch in the approach to handling the BREFs, the Ammonia BREF never got to the final IEF approval.

With the new approach to BREFs having selected family BREFs for bulk inorganic gases and liquids to be done in 1999, on the one hand, and bulk inorganic solids for the year 2000, on the other hand, it became clear that the booklets required some checking to ensure that all the mentioned data were up to date. This task was started in 1998 and will be finalized this year, before the kick-off meeting of the TWG “Inorganic Gases and Liquids” so that the updated booklets will be included in the corresponding family BREFs as process BREFs. EFMA is therefore participating actively in the relevant CEFIC Shadow Groups elaborating the proposals that will be given to the Bureau expert as the industry contribution. The EFMA updated booklets will also be available for download on the EFMA web site.

Conclusion

The IPPC Directive is a very powerful tool for the establishment of a cleaner industrial environment in Europe, provided no distortions are introduced by national authorities through the application of the included
subsidiarity principle. Such distortions can be avoided by strictly following indications provided by BAT reference documents.

Industry has clearly shown a proactive stance in the case of the IPPC Directive with EFMA spearheading the effort of the fertilizer industry well in advance of all other sectors. This effort will have to be continued in a rather intense way for at least the next 2 years, until the IEF has finalized the relevant family BREFs. A further but less demanding effort will be necessary afterwards to follow up on possible updating efforts in that BREFs are not meant to be “carved in stone” once and for all.

Appendix

Work Program for the Information Exchange on BAT Under the IPPC Directive

1997
- Primary/Secondary Steel
- Cement and Lime
- Paper/Pulp
- Horizontal 1: Cooling Systems

1998
- Ferrous Metals Processing
- Non-Ferrous Metals Production and Processing
- Glass
- Chloralkali
- Textile
- Tanneries
- Horizontal 2: Monitoring of Emissions

1999
- Refineries
- Smitheries and Foundries
- Large Volume Organic Chemicals
- Large Volume Gaseous and Liquid Inorganic Chemicals
- Intensive Livestock Farming
- Horizontal 3: Emissions From Storage (dangerous substances and bulk materials)
- Horizontal 4: Waste Water and Waste Gas Treatment/Management in the Chemical Industry
- Horizontal 5: Cross-Media and Economic Aspects

2000
- Large Volume Solid Inorganics
- Hazardous Waste Disposal/Recovery
- Slaughterhouses/Animal Carcasses
- Food and Milk

2001
- Large Combustion Plants
- Coal Liquefaction
- Surface Treatment of Metals
- Asbestos
- Ceramics
- Polymers
- Surface Treatment Using Solvents

2002
- Specialty Inorganics
- Organic Fine Chemicals
- Municipal Waste Incineration
- Nonhazardous Waste Disposal
- Landfills
Fertilizer Production and Environmental Protection: Petrokemija Ltd. Fertilizer Company

Ivica Losso, Deputy Director for Fertilizer Production
Petrokemija Ltd., Fertilizer Company
Kutina, Croatia

Introduction

Petrokemija Ltd. Fertilizer Company located at Kutina is the only fertilizer, carbon black, and bentonite clay manufacturer in Croatia. The first phase of the industrial complex for the manufacture of fertilizers, which had a capacity of 740,000 mtpy of different fertilizers, was built in 1968 at Kutina, owing to an industrial tradition dating back to 1939, the abundance of oil and gas wells, and the availability of trained technical staff.

With the erection of the second phase and startup in 1984, the capacity of the Kutina fertilizer complex was increased to 1.9 million mtpy. With the shutdown of the Ammonia 1 and Urea 1 plants in 1993, capacity of the fertilizer production is now about 1.5 million mtpy. Over the past 31 years, the Kutina fertilizer complex has manufactured about 30 million mt of different fertilizers.

The technology for the manufacture of fertilizers was imported from the most developed countries. Although highly complex, this technology was mastered in a short time by Kutina’s technologists, who are constantly improving it and introducing their own innovations.

Production Processes

Fertilizers are produced using raw phosphate rock, sulfur, and natural gas. With natural gas, steam, and nitrogen from the air, synthesis gas is produced. From the high-pressure synthesis gas (3H₂ + N₂), ammonia is produced. From ammonia, nitric acid is produced by oxidation; nitric acid plus ammonia results in ammonium nitrate (AN). By adding calcium carbonate to the ammonium nitrate, calcium ammonium nitrate (CAN) is obtained. Urea is produced at high pressure from ammonia and carbon dioxide.

NPK fertilizers are produced by the direct attack of raw phosphate rock with nitric acid or sulfuric acid (produced from sulfur) followed by neutralization with ammonia and the addition of potassium salts.

Urea is produced in prilled form, and CAN as prilled or granulated fertilizer. NP and NPK fertilizers are produced as granules in complex form, meaning that every granule contains all three nutrients (N, P₂O₅, K₂O). NP, PK, and NPK fertilizers can also be produced by dry bulk blending. Fertilizers can also be produced in liquid form. The schemes for fertilizer production at Petrokemija Ltd. Fertilizer Company are shown in Figure 1.

Following the world trend, Petrokemija produces mostly granulated and prilled fertilizers, straight nitrogen, and NPK fertilizers with various ratios of plant nutrients to provide a medium- and high-nutrient concentration containing various ratios of plant nutrients, special fertilizers with additives, and nitrogen solutions. The capacity and the various production units and nutrient content of various products are shown in Tables 1 and 2.

With its up-to-date technology and its product range and product quality, which are up to international standards, Petrokemija is able to meet the complex needs of the international fertilizer market.

Due to their outstanding quality, Kutina’s fertilizers have been accepted by consumers in numerous countries in Europe, North and South America, Africa, and Asia.

Clay Factory products are bentonite clays, cattle feed additives, foundry additives, and other products such as cleaning materials. The maximum capacity of clay production is 59,000 mtpy.

With an annual capacity of 36,000 mt, carbon black production by the oil furnace process is the second business at Petrokemija. The product range includes carbon black used primarily in the rubber industry as well as black pigments for paints, coatings, and plastics. We
Figure 1. Schemes for Fertilizer Production at Petrokemija Ltd. Fertilizer Company.
have developed our own carbon black technology, which is being sold on the world market.

Mineral fertilizers account for about 90% of the total financial outcome of Petrokemija, while carbon black accounts for about 6% and bentonite clay products for 2%. Other products and services account for an additional 2%.

Quality is the best way to achieve customer satisfaction, which, in turn, ensures customer loyalty and business success of the company, in general. This fact is given the utmost importance and consideration in the company business policy.

We introduced and, in 1995, certified a quality management system (QMS) in accordance with the ISO 9002 international standard, and in 1998 confirmed this certification by upgrading to the ISO 9001 standard.

Table 1. Capacity of Petrokemija Production Units

<table>
<thead>
<tr>
<th>Unit</th>
<th>Daily capacity (metric tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>1,360</td>
</tr>
<tr>
<td>Nitric acid</td>
<td>1,260</td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>1,500</td>
</tr>
<tr>
<td>Phosphoric acid (P₂O₅)</td>
<td>500</td>
</tr>
<tr>
<td>Urea</td>
<td>1,500</td>
</tr>
<tr>
<td>CAN (27% N)</td>
<td>1,250</td>
</tr>
<tr>
<td>Industrial-grade AN</td>
<td>500</td>
</tr>
<tr>
<td>UAN solution</td>
<td>650</td>
</tr>
<tr>
<td>Ammonium phosphates</td>
<td>1,000</td>
</tr>
<tr>
<td>Complex fertilizers</td>
<td>2,700</td>
</tr>
</tbody>
</table>

Table 2. Nutrient Content of Various Fertilizer Products

<table>
<thead>
<tr>
<th>Nitrogen Fertilizers (% N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
</tr>
<tr>
<td>CAN</td>
</tr>
<tr>
<td>AN</td>
</tr>
<tr>
<td>AN</td>
</tr>
<tr>
<td>UAN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Complex Fertilizers (% N - P₂O₅ -K₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-20-30+S</td>
</tr>
<tr>
<td>6-18-36</td>
</tr>
<tr>
<td>7-14-21+S</td>
</tr>
<tr>
<td>7-20-30</td>
</tr>
<tr>
<td>8-16-24</td>
</tr>
<tr>
<td>8-26-26</td>
</tr>
<tr>
<td>10-20-30</td>
</tr>
<tr>
<td>10-30-20</td>
</tr>
<tr>
<td>13-10-12</td>
</tr>
<tr>
<td>13-10-12</td>
</tr>
<tr>
<td>15-15-15</td>
</tr>
<tr>
<td>20-10-10</td>
</tr>
</tbody>
</table>

Environmental protection in Fertilizer Production

Rapid economic growth and expansion of the human population have produced a number of local, regional, and global environmental problems. Presently, the most severe environmental threats are global in nature. The greatest global problems that require international action are global warming, depletion of the ozone layer, and water pollution.

The Republic of Croatia has ratified numerous international conventions and concluded a number of international agreements in the field of environmental protection.

Petrokemija, engaged in the manufacture and trade of carbon black, bentonite clays, and mineral fertilizer, maintains and continuously develops its QMS in compliance with ISO 9000. Good care of environmental protection is part of our policy of quality, security, health, and environmental protection.

Petrokemija began with the construction of an environmental protection system in the early 1970s, immediately after the initiation of the global environmental initiative. The environmental protection system in our company includes organization, staff, procedures, plans, and equipment. We are constantly improving our performance by the addition of facilities and fine-tuning of operational practices.

Environmental issues concerning the fertilizer industry involve the whole chain of activities including production, storage, transport, and use. In addition to potential pollution of air, water, and soil, there are hazards to be avoided in each section of this chain including questions of occupational health and safety for all who handle these products. A discussion of the environmental issues
involved in the production of fertilizers at Petrokemija follows.

**Air Protection**

The processes used in fertilizer production have the potential of producing gaseous and solid air pollutants. The main pollutants in Petrokemija’s emissions to the atmosphere are ammonia \( (\text{NH}_3) \), nitrogen oxides \( (\text{NO}_x) \), sulfur dioxide \( (\text{SO}_2) \), fluoride \( (\text{F}) \), and solid particulates.

Emission levels at some sources of the first-phase (older) plants, in spite of being within design limits, exceed Best Available Techniques (BAT) emission levels. In order to abate emissions, several improvements have been made, and others are in the planning stage.

In construction of the second-phase plants, the advantage was given to the process in which the same product is obtained, but with less environment pollution. Many preventive and control measures are applied including the following:

- A double contact/double absorption process for sulfuric acid production with emissions of \( \text{SO}_2 \) at a world standard level of below 1.000 mg/NM³.
- Use of natural gas instead of oil as feedstock in ammonia and energy production, thus virtually eliminating \( \text{SO}_2 \) emissions.
- Scrubbing of waste gases in CAN, NPK, and phosphoric acid production to reduce emissions of \( \text{NH}_3 \), F, and particulate to the atmosphere.
- Use of an efficient absorption column in the nitric acid process to reduce \( \text{NO}_x \) emissions to a world standard level of below 400 mg/NM³.
- Use of a bag filter system in the rock phosphate grinding section of the phosphoric acid plant to decrease particulate emissions.

All the stacks are regularly monitored using continuous monitors in the sulfuric acid and power plants and portable analyzers and isokinetic samplers, bubble gas trains, and laboratory analyses for the other plants. The relative share of pollutants in air emissions from Petrokemija is shown in Figure 2.

Petrokemija’s laboratory for environmental protection also provides continuous monitoring of air pollutant concentrations and meteorological parameters of the Kutina area. Monitoring of urban area quality started in 1976 in association with the Institute for Medical Research and Occupational Health and the National Hydrometeorological Bureau in Zagreb. The local monitoring network now consists of six stations equipped with devices for 24-hour sampling.

The results of long-term monitoring indicate that air quality of the Kutina area is related to the Petrokemija fertilizer industry. Air quality has improved as a result of measures undertaken in the factory to decrease emissions to below limit levels. The trends in atmospheric levels of ammonia, fluoride, and \( \text{SO}_2 \) in the Kutina area for the period 1978-97 are shown in Figures 3, 4, and 5.

![Figure 2. Relative Share of Pollutants in Air Emissions From Petrokemija.](image)

![Figure 3. Average Annual Concentration of Ammonia in Kutina Area Air for Period 1978-97 and Comparison With Recommended (PV) and Maximum Allowable Concentration (GV).](image)
In order to prevent water pollution, the following special units and equipment have been installed:

- For effluent waters from the nitric acid, CAN, and NPK plants in which ammonia and nitrates prevail as pollutants, an ion exchange unit has been installed.
- For phosphoric acid plant wastewater polluted by fluoride, a lime neutralization unit has been installed.
- Urea-polluted waters from the urea plant are treated in a hydrolyzer stripper to decompose the urea and released ammonia, which is returned into the process. The treated water is then discharged.
- Acidic wastewater from the sulfuric acid plant is neutralized with lime before discharge.

Effluent from the outlet channels is analyzed using pH meters, flow indicators, and automatic samplers for a continuous check on the quality and quantity of effluents. If required, corrective actions are taken immediately.

Data on trends in wastewater pollutant concentration are shown in Figures 7, 8, and 9.

The results of monitoring indicate that water pollution has gone down year by year. There

Water Protection

The main pollutants in wastewater from the Petrokemija fertilizer plants include (1) ammoniacal and nitrate nitrogen, (2) phosphates, (3) fluorides, (4) oils, and (5) suspended solids. After treatment, all process wastewater, together with rain and sanitary waste after treatment in a municipal unit, are directed to the Kutinica River. The relative share of nitrogen, fluoride, and suspended matter discharged in wastewater is shown in Figure 6.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Relative Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia and nitrates</td>
<td>33%</td>
</tr>
<tr>
<td>Suspended matter</td>
<td>64%</td>
</tr>
<tr>
<td>Fluorides (as F)</td>
<td>3%</td>
</tr>
</tbody>
</table>

Figure 5. Average Annual Emission Factor for Sulfur Dioxide for Sulfuric Acid Plant for Period 1995-97 and Comparison With Maximum Allowable Emission Factor After Year 2004 (GV).

The relative share of total pollutants discharged into Kutinica River through Petrokemija Wastewater.

Figure 6. Relative Share of Total Pollutants Discharged Into Kutinica River Through Petrokemija Wastewater.
were no critical situations in the last 6 years that resulted in a harmful impact on the environment. The cadmium level in wastewater is not a matter of concern because its concentration is below 5 µg/L, which is the limit value for drinking water.

**Solid Waste**

The processes involved in the production of fertilizers result in different solid wastes. Petrokemija takes a lot of care relative to the safe disposal of these solid wastes. Figure 10 shows the relative share of solid wastes produced by Petrokemija during the period 1995-98.

Almost 99% of total solid wastes is composed of phosphogypsum and fluoride water-neutralization sediment (calcium fluoride). Calcium fluoride, the solid waste after treatment of fluoride wastewater, is deposited in the separate land disposal area. The phosphogypsum byproduct from the production of phosphoric acid is also deposited in a separate land disposal area.

Spent catalysts from ammonia and sulfuric acid production are recycled to catalyst manufacturers or other metal handling companies for reclamation of the valuable metals.

**Phosphogypsum Disposal Pond**

A major environmental problem facing the fertilizer industry
is the safe disposal of the phosphogypsum produced from the production of phosphoric acid by the wet process phosphoric acid process. About 5 mt of phosphogypsum is generated per metric ton of \( \text{P}_2\text{O}_5 \) produced as phosphoric acid. Phosphogypsum (\( \text{CaSO}_4\cdot2\text{H}_2\text{O} \)) contains the following impurities that are considered to be potentially harmful: residual acidity (\( \text{P}_2\text{O}_5 \)), fluorine compounds, trace elements (heavy metals), and radioactivity. The concentration of these unwanted impurities depends on the type of phosphoric acid process used and the composition of the phosphate rock. Two methods can be used to dispose of phosphogypsum—discharging into water (rivers/oceans) and dumping on land.

Petrokemija phosphoric acid is produced by the dihydrate process. Byproduct phosphogypsum is hydraulically transported (pumped) from the phosphoric acid plant to the land disposal site located approximately 5 km from the factory. Geological and hydrogeological studies were made before construction of the disposal site. The phosphogypsum disposal site is divided into five basins and covers a total area of about 1.6 km\(^2\). The capacity is 7x10\(^6\) m\(^3\) when filled to the level of the earthen dams.

The present deposit contains 5x10\(^6\) mt of phosphogypsum and 1 x 10\(^8\) m\(^3\) pond water. The pond water is used for transportation of the phosphogypsum, and any excess pond water is treated with lime before being discharged. Because of the possible impact on the environment, Petrokemija pays special attention to the phosphogypsum disposal area. The security of the disposal site is under the constant care of the plant staff. The monitoring system consists of the following:

1. Monthly measuring of groundwater quality from 5 piezometers (wells).
2. Continuous monitoring of the gaseous fluoride concentration in the air at the pump station.
3. Measuring of natural radioactivity of soil, underground water, air, and phosphogypsum once to twice a year.
4. Measuring of surface water in winter and spring when the surrounding area is flooded.
5. Measuring of fluoride content in grass and vegetation foliage once to twice a year.
7. Measuring of settled and dried phosphogypsum several times a year.

The phosphogypsum landfill is a matter of international concern through the International Atomic Energy Agency (IAEA) technical cooperation on regional environmental restoration projects for countries in Central and Eastern Europe.

The monitoring of the disposal area is for the most part covered by Petrokemija’s own laboratories except for the radioactivity monitoring, which is supported by the Institute for Medical Research and Occupational Health, Institut “R. Boskovic,” and the Hazardous Waste Management Agency.

Figure 11 shows the deposited phosphogypsum (annually and cumulatively), radium (\(^{226}\text{Ra}\)) specific activities in underground water, and Working Level Month (WLM) at the dam of the landfill. The Croatian legislation is based on the latest IAEA recommendations taking 1,000 Bq/m\(^3\) as the maximum permissible level for \(^{226}\text{Ra}\) in drinking water, which is a derived concentration for a group of individuals. According to the results, the specific activity of radium measured in samples of underground water is lower than the permissible radium concentrations in drinking water, which proves that leakage
of radionuclides does not occur. WLM measurements follow the results of radiochemical analysis of $^{226}$Ra. Slightly higher values were determined in 1993, but later measurements show a steady decrease. The latest guideline for occupational exposure to radon decay product (WLM) as recommended by the IAEA is 4 WLM/year averaged over 5 consecutive years, or 10 WLM in any single year. According to these results, even the highest WLM value is lower than permissible occupational exposure and poses no risk to workers.

Figure 12 shows the average annual values of some specific parameters of underground water quality in 1990 and 1996 compared with limit values. In 1990 the landfill was extended with two additional disposal basins and a new network of piezometers was installed. The average annual values of pH, cadmium, phosphates, sulfates, and fluorides in underground water for 1990 and 1996 are compared with limit values. The results show that at the present time there is no increase in the measured values of chosen indicators of underground water quality compared with background. All results are below the limit values.

As the monitoring results show, the harmful impact of the phosphogypsum landfill on the environment and human health has been minimized.

**Conclusion**

Ensuring the protection and improvement of environmental quality through innovation and improvement of the production processes is a permanent task of our company. Through the installation of environmental protection equipment, pollution has been considerably reduced but not totally eliminated. However, the influence on the environment caused by fertilizer production in Petrokemija, Kutina, is under permanent control, and results of monitoring show a continuous decline in the emission of pollutants to the atmosphere, water, and soil.

Every measure of environmental protection is connected with large investment costs; thus, Petrokemija is trying to find the optimal equilibrium between possible damage from individual pollutants and the financial costs of reducing or preventing pollution.

Activities that are now underway and will be continued in the future to further protect the environment include the following:

- Purchasing “good” raw materials.
- Improving and revamping production processes.
- Performing risk assessment studies.
- Improving the existing monitoring system.
- Implementing environmental management systems (EMS)
according to the requirements of ISO 14000 standards.

- Continuing cooperation with state and local authorities and scientific institutions.

**Acknowledgments**

The author wishes to thank all those who helped prepare this paper, especially to:

Mrs. Katica Bozicevic, Senior Engineer for Environmental Protection

Mrs. Grozdana Avirovic, Chief for Environmental Protection Laboratory

Mr. Stjepan Leakovic, Senior Engineer for Water Treatment

**Bibliography**


**Introduction**

There is growing international pressure to care for the environment. This pressure has been steadily building since the 1960s, but unlike the early days, the issues now are being taken very seriously at the government level and the customer level. For businesses there are now a number of “strategic business drivers,” for example:

- **International Protocols**—The best known of these protocols is probably the Rio Declaration on Environment and Development. This was a result of a United Nations Conference in June 1992, which reaffirmed and built upon a similar Declaration in Stockholm in 1972. A total of 27 principles were set out. Many of these principles address sustainable development, the need to align actions to local circumstances, and cooperation and involvement at all levels of society.

- **Globalization of Business**—International businesses frequently apply common environmental standards throughout the world, and they are starting to expect similar commitments from the organizations with which they do business.

- **Scientific Knowledge**—The increasing body of scientific knowledge is providing evidence that many routine processes and actions have significant impacts on the environment. For example, it is now accepted that ozone depletion and global warming exist.

- **Media Events**—World news coverage has highlighted many incidents such as the Exxon Valdez oil tanker disaster in Alaska. This resulted in colossal costs for the oil company, exceeding a billion dollars. Out of this came the “Valdez Principles” (now CERES), which resulted from pressure from shareholders, insurance companies, and interested parties. This put in place a regime that would lessen the likelihood of a similar accident.

- **Pressure Groups**—In the 1960s Greenpeace was considered to be ineffective; it and other organizations now have significant international influence.

All these strategic business drivers interrelate and contribute to making the general public, businesses, and governments more aware of the dangers of not protecting the global environment.

Tighter environmental legislation and the birth of the international standard (ISO) 14001 on environmental management are direct consequences of international pressures. And there is no turning back. The requirement to look after our planet will only increase.

But why should an individual business elect to establish an Environmental Management System (EMS) other than for altruistic reasons? What are the benefits to the bottom line of an organization? This paper will address these questions.

**Business Benefits of an EMS**

There are many business benefits that can be achieved by installing an EMS, and these can be summed up as follows:

- **Risk Management**.
- **Gaining Competitive Advantage**.
- **Opportunities for Cost Savings**.
- **Improved Relationships With the Community, Stakeholders, and Regulators**.
- **Confidence of Financial Institutions**.

A brief discussion of these business benefits follows.

**Risk Management**

In order to manage environmental risks, it is vital for a company to understand the environmental issues associated with its activities, products, and/or services. It is also important to relate these to the location of
the site and relevant environmental legislation. ISO 14001 requires that these issues be understood, documented, and acted upon. When a risk is identified and understood, it is possible to put plans in place that will reduce the likelihood of an environmental accident. It is also possible to prioritize actions and any capital investment that may be needed. It may be that the ISO 14001 process will result in a more effective risk management program and a less expensive implementation cost—two clear business wins.

The result of an environmental incident can be very damaging, and the consequences may not be limited to environmental damage. Other factors that may be damaged are the reputation of a company, which can result in lost business, poor staff morale, and possibly a reduction in shareholder confidence. These issues all affect profitability. An incident may also lead to a breach of environmental legislation with consequential heavy fines and cleanup costs. Experience has shown that cleanup activities may be considerably more costly than the fine. Managing risk, therefore, is not only good for the environment but also potentially good for the well-being of the business concerned.

Gaining Competitive Advantage

As international interest and positive action are growing in the environmental arena, so too is the opportunity to gain competitive advantage over business competitors. Organizations and their stakeholders are becoming increasingly concerned about the environmental credentials of the organizations with which they are doing business. It is not uncommon for suppliers to have to declare their environmental policies prior to gaining a contract. Some organizations require that their suppliers have a certified EMS in place.

The message to organizations that do not want to risk being excluded from international trading opportunities is to start acting now; it can take between 12 and 18 months to establish a certifiable EMS. There is also a clear opportunity to proactively establish a business dialogue with potential customers who have declared their corporate responsibility towards the environment.

**Opportunities for Cost Savings**

Taking environmental initiatives can save money. For example, ISO 14001 requires an organization to identify the environmental aspects of its activities. This will invariably lead to a better understanding of its processes and their level of efficiency. This in turn should lead to the setting of such objectives as purchasing, using, and wasting less material and gaining higher efficiencies from combustion and chemical processes. The result is a clear win for both the environment and the cost base of the business.

**Improved Relationships With Community, Stakeholders, and Regulators**

ISO 14001 requires that “top management shall define the organization’s policy and ensure that it is available to the public.” Thus, there is a requirement to make information publicly available—the fact that a company has been certified is in the public domain. There is some evidence to suggest that if accurate and meaningful information is made available, coupled with objectives and targets that will bring about a real and demonstrable improvement in environmental performance, relationships with the community and pressure groups improve.

**Confidence of Financial Institutions**

A well-managed company is an interesting partner. This management concerns business risks and environmental risks. Success of any EMS implementation program will depend, to a great extent, upon the commitment and involvement of company’s top management, which must be passed on to other managers and employees, allowing momentum to build behind the program.

Companies should identify their specific advantages (including any possible disadvantages) of implementing an EMS. This information can be prioritized and evaluated by top management (Table 1).

**Conclusion**

The following is a summary of business benefits that may accrue as the result of effective implementation of an EMS.

- There is increasing awareness of the importance of environmental issues by company stakeholders (customers, parent company, employees, regulators, and neighbors).
- Well-managed organizations know their potential business risks, which include environmental risks.
- Identification and effective management of environmental impact can lead to a competitive advantage.
- All businesses have an environmental impact that can be managed in a positive way.
- Risk assessment and the production of an aspects/impact register. Once such a register is produced and updated as appropriate, the register can be used as the basis for prioritization of action and the production of action plans.
- Some actions are not necessarily costly to implement and can lead to fairly quick improvements and resulting cost reductions, for example, waste segregation and reuse, and
## Table 1. Advantages and Disadvantages of Installing an EMS

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>• Avoids fines</td>
<td>• No obvious return of investment</td>
</tr>
<tr>
<td></td>
<td>• Identifies possible areas that can save costs, such as recycling, landfill costs, utilities</td>
<td>• Implementation costs—financial and time</td>
</tr>
<tr>
<td></td>
<td>• Spreads costs of environmental action rather than having to be forced by legislation to install immediately</td>
<td>• Maintenance/review costs</td>
</tr>
<tr>
<td><strong>Marketing</strong></td>
<td>• Offers potential competitive advantage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Improves public relations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Strengthens position on share market</td>
<td></td>
</tr>
<tr>
<td><strong>Training</strong></td>
<td>• Improves environmental awareness</td>
<td>• Cost</td>
</tr>
<tr>
<td></td>
<td>• Educates operators on how process may cause environmental liabilities</td>
<td>• Additional training required possibly required</td>
</tr>
<tr>
<td></td>
<td>• Increases production rate (enthused employees)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reduces potential for environmental incidents through contingency awareness</td>
<td></td>
</tr>
<tr>
<td><strong>Public Perception</strong></td>
<td>• Demonstrates concern for the environment</td>
<td>• Possibility of contradicting current company programs</td>
</tr>
<tr>
<td></td>
<td>• Appears proactive not reactive to legislation</td>
<td>• Problems in amalgamating systems or running multistandards simultaneously</td>
</tr>
<tr>
<td><strong>Monitoring</strong></td>
<td>• Identifies harmful substances outside of the process</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Improves the use of raw materials and energy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Improves process operation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Facilitates identification of impact</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Creates and builds detailed and relevant environmental data</td>
<td></td>
</tr>
<tr>
<td><strong>Management</strong></td>
<td>• Provides a structured framework for management of environmental issues</td>
<td>• Possibility of contradicting current company programs</td>
</tr>
<tr>
<td></td>
<td>• Allows a coordinated management approach to be taken across the company from an established baseline of information</td>
<td>• Problems in amalgamating systems or running multistandards simultaneously</td>
</tr>
<tr>
<td></td>
<td>• Complements other quality standards</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Helps anticipate future legislation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Facilitates full European Business integration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Establishes better relations with regulatory and licensing authorizations</td>
<td></td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td>• Assists Integrated Pollution Control (IPC) authorization, and consent licensing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Elicits positive response from investors, lenders, and insurers</td>
<td></td>
</tr>
</tbody>
</table>
reduction in use of raw materials and energy.

- Where capital investment is involved to bring about improvements, presentation of the systematic investigations arising out of the compilation of the aspects/impact register can be used as justification.

- Legislative requirements concerning “environmental matters” are comprehensive and subject to change. Using the EMS for systematic identification and implementation allows a seamless approach to proposed changes in legislation.

- Competitive advantage can be obtained from effective implementation of an EMS by:
  - Being aware of, and meeting, legislation and stakeholders’ requirements.
  - Identifying and managing “environmental risks” to the business.
  - Identifying and managing improvements in environmental effects leading to cost reduction.
Obtaining ISO 9000 and ISO 14000 Certification
A Case Study: Lovochemie, a.s. Plc.

Vladimír Novotný
Unipetrol, Plc.

Introduction

Lovochemie, Plc. is a Czech private joint-stock company operating in the European market. During the period 1993–99, Lovochemie implemented a quality management system (QMS) for selected key production units. Some production units were certified by ISO 9002. This process of QMS implementation and certification of production units in our company is expected to be finalized in the year 2000. Some products of Lovochemie have been awarded the prestigious mark of high quality “CZECH MADE.”

The next step is to improve existing management systems in the company through the process of environmental management system (EMS) implementation. This ongoing process was started recently. A functional QMS has been identified as an important advantage for EMS development and implementation. EMS certification by ISO 14001 is expected to be finished in the year 2000.

Background

The chemical industry and fertilizer production have nearly a 100-year tradition in Lovosice. A fertilizer factory has operated since 1904 and an artificial silk company since 1921. During the period 1958–98, two different production processes were merged into one enterprise, Northern Bohemian Chemical Works (National Enterprise), which later became Lovochemie, Plc. Since 1998, Lovochemie has again focused its activities on fertilizer production.

The 100-year history of the chemical industry in Lovosice brings important advantages in skilled employees and a traditional position in the European market. However, environmental burdens from the past and some obsolete technical facilities in Lovochemie represent problems that must be solved with respect to environmental issues.

Milestones of Chemical Production, Lovosice, 1904 to Date

1904 Adolf Schram Factory, production of sulfuric acid and superphosphate.
1921 The Czech artificial silk factory.
1945 The Czech Silk, National Enterprise.
1950-57 Construction of the Factory for Industrial Fertilizer.
1958 Merging two previous factories in the Northern Bohemian Chemical Works.
1959 Production of carboxymethylcellulose (LOVOSA) started.
1960 Production of viscose cord rayon started.
1964 New production unit for superphosphate.
1966 Viscose silk production ceased.
1967 Start of compound NPK fertilizer production and new nitric acid production.
1990 Superphosphate and sulfuric acid production ceased.
1991 New calcium ammonium nitrate production unit.
1993 Joint stock company Lovochemie, a.s. (Plc.) established.
1994 Lovochemie accepted as International Fertilizer Industry Association (IFA) Member.
1996 Privatization of Lovochemie, Plc. completed.
1998 Viscose cord rayon production unit sold to Glanzstoff, Ltd. Company.

Lovochemie, Plc.

Lovochemie, Plc. represents a medium-size enterprise, specializing in the production of heavy chemicals and industrial fertilizers. Lovochemie is located in the vicinity of the central Bohemian town Lovosice on the banks of the navigable river Labe, where the company has its own river
port and facilities. With regard to transport, the location of Lovochemie, Plc. is favorable. The close contact with the Elbe waterway and a direct connection to the railway and highway system enable the company to have ecologically optimum domestic and international transport. The main raw materials for Lovochemie production are ammonia and urea, which are mostly supplied by Chemopetrol, Plc. (Unipetrol Group) located 40 km from Lovochemie and transported by rail.

The company is now being restructured in order to focus its activities on fertilizer production as a core business activity. Lovochemie had 996 employees at the end of 1998. Its sales in 1998 totaled 2.6 billion CZK (US $74 million).

**Basic Characteristics of Lovochemie Production**

### Fertilizers—77% turnover of company (1998)

- Nitrogen fertilizers: $157,343 \times 10^3 \text{ t N}$
- Phosphorus fertilizers: $14,959 \times 10^3 \text{ t } P_2O_5$
- Potassium fertilizers: $12,961 \times 10^3 \text{ t } K_2O$

### Viscose cord rayon—14% turnover of company

- Viscose cord rayon: $3,730 \times 10^3 \text{ t}$

### Others

- Carboxymethylcellulose: $1,258 \times 10^3 \text{ t}$

### Electricity generation

- Production: 39,000 MW
- Purchase: 58,000 MW
- Electricity sale: 8,000 MW

The ancestor of the present company—Northern Bohemian Chemical Works (national enterprise)—was privatized in 1993 and transformed into the joint-stock company Lovochemie, Plc. Since 1993 the portfolio of shareholders has changed; full privatization of the company was finalized in 1996. The changes in shareholders since 1995 are shown in Table 1.

At present, two major Czech industrial groups, Unipetrol Group and Agrofert Group, hold controlling shares in Lovochemie, Plc. The present structure of shareholders is as follows:

<table>
<thead>
<tr>
<th>% Equity</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>39.8</td>
<td><strong>Proferta, Plc.</strong></td>
</tr>
<tr>
<td>100%</td>
<td>100% Agrobohemia, Plc.</td>
</tr>
<tr>
<td>53.3</td>
<td><strong>Agrobohemia, Plc.</strong></td>
</tr>
<tr>
<td>50%</td>
<td>50% Agrofert, Plc.,</td>
</tr>
<tr>
<td></td>
<td><strong>Agrofert Group</strong></td>
</tr>
<tr>
<td>50%</td>
<td>50% Unipetrol, Plc.,</td>
</tr>
<tr>
<td></td>
<td><strong>Unipetrol Group</strong></td>
</tr>
<tr>
<td>93.1</td>
<td></td>
</tr>
</tbody>
</table>

### Long-Term Strategy of Lovochemie, Plc.

The development of Lovochemie, Plc. during the last 10 years can be characterized by privatization, reorganization, and a process of improving the efficiency of all activities in the company. Lovochemie, Plc. has recently adopted a long-term strategy focused on addressing quality and environmental issues. Basic elements of quality and environmental aspects are defined in a long-term strategy as follows:

- Restructure all activities.
- Focus on core business—fertilizer production.
- Maintain position in world fertilizer market.
- Introduce QMS.
- Improve quality of products.
- Introduce EMS in a simple and efficient way.

This strategy was anchored in the long-term plan of the company that was approved in 1997 and 1998. Investment priorities were defined as follows:

- Renovation of old facilities (storage facilities for calcium nitrate and compound NPK fertilizers).
- Environmental investments in desulfurization of coal boiler stack gas and emissions reduction in NPK production.
- Investments for improving the quality of key products (calcium ammonium nitrate, cal-

### Table 1. Lovochemie, Plc. Shareholder Portfolio Development, 1995-98

<table>
<thead>
<tr>
<th>Year</th>
<th>1995</th>
<th>1997</th>
<th>1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Property Fund</td>
<td>51.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Investment privatization funds</td>
<td>25.3</td>
<td>2.9</td>
<td>-</td>
</tr>
<tr>
<td>Individual possessors (investment coupons)</td>
<td>14.6</td>
<td>13.8</td>
<td>6.9</td>
</tr>
<tr>
<td>Town of Lovosice</td>
<td>5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Restitution and Grand Fund</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Employees</td>
<td>0.1</td>
<td>0.1</td>
<td>-</td>
</tr>
<tr>
<td>Proferta, Plc.</td>
<td>55.7</td>
<td>39.8</td>
<td>-</td>
</tr>
<tr>
<td>Agrofert Holding, Plc.</td>
<td>-</td>
<td>11.1</td>
<td>-</td>
</tr>
<tr>
<td>Juristic persons</td>
<td>-</td>
<td>16.4</td>
<td>-</td>
</tr>
<tr>
<td>Agrobohemia, Plc.</td>
<td>-</td>
<td>-</td>
<td>53.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
The company will provide con-
mium ammonium nitrate with magnesium, compound NPK fertilizers, and compound fer-
tilizers with sulfur).

- Preparation of new compound fertilizers as key products.

**Obtaining ISO 9000 Certification—QMS**

Increased global competition in the fertilizer market has led to increasingly more stringent cus-
tomer expectations with regard to quality. To be competitive and to maintain good economic per-
formance, the producer needs to employ increasingly effective and efficient systems, which should result in continual improve-
ments in all aspects of quality and increased satisfaction of customers and other stakeholders. An efficient way to improve a position of a company in terms of quality is through the implement-
ment of a quality-oriented management system. A primary purpose of quality management is to improve systems and pro-
cesses so that continual improvement of quality can be achieved.

In Lovochemie, Plc., the pri-
mary objectives and responsibili-
ties for quality are understood as follows:

- The company will achieve, maintain, and seek to improve continuously the quality of its products in relationship to the requirements for quality.

- The company will improve the quality of its operations, so as to continually meet all custo-
mers’ and stakeholders’ expectations.

- The company will provide confidence to the customers and other stakeholders that the re-
quirements for quality are being achieved and that quality system requirements are fulfilled.

During the period 1993-99, Lovochemie, Plc. established, implemented, and certified a QMS in several steps. The pro-
cess of QMS implementation be-
gan with analysis provided by SUPROCERT, an external con-
sulting company. A pilot project, started in 1993, focused on the calcium ammonium nitrate pro-
duction unit. Milestones of QMS preparation, implementation, and certification are listed:

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>Decision by senior management to introduce QMS in Lovochemie.</td>
</tr>
<tr>
<td>1993-95</td>
<td>Preparation of calcium ammonium nitrate production unit for certification.</td>
</tr>
</tbody>
</table>
| 1994 | Analysis by external consulting organiza-
tion, SUPROCERT: |
| 1995 | Detailed scheduling of QMS implementation prepared and accepted. |
| 1996 | Production certification by RW TUV for calcium ammonium nitrate and calcium ammonium nitrate with magnesium. |
| 1999 | Production recerti-
cation for calcium ammonium nitrate and calcium ammo-
nium nitrate with magnesium and cert-
tification of carb-
oxymethylcellulose (LOVOSA). |

Now Lovochemie, Plc. is pre-
paring a QMS audit for its prod-
ucts Lovatan and Milevit (abrasives). Certification of these two products is expected in 2000. QMS documentation is also being prepared for compound NPK fertilizers with certi-
fication expected in 2001. For the production of urea-ammonium nitrate solution fertilizer (DAM 390) and the production of nitric acid, preparation of QMS documentation has recently be-
gun. QMS certification for these two production units is expected in 2002, which will finalize the QMS process for all production activities of the company.

**QMS Achievements**

As a result of QMS implement-
ation and certification, Lovochemie, Plc. has improved its position in both the domestic and European fertilizer markets. This achievement was of crucial significance in a period of domes-
tic market recession and stagna-
tion of the European fertilizer market.

QMS certification of viscose cord rayon was a primary condi-
tion for engaging in the European automobile market. A contract between Lovochemie, Plc. and the Continental Company is one good example of the practical positive effect of QMS certification for the company: the sale of the viscose cord rayon produc-
tion unit to Glanzstoff CR Ltd. is another. QMS certification was essential.

Two Lovochemie Plc. products, calcium ammonium nitrate and calcium ammonium nitrate with magnesium, were awarded the prestigious mark “CZECH MADE” (the Czech equivalent to “European quality price” or “Baldrige price”) as an acknowl-
edgment of the high quality.

**Obtaining ISO 14000 Certification—EMS**

Environmental management systems in the Czech Republic represent a relatively new initia-
tive. The first two EMS certifica-
tions in the Czech Republic were in 1996 (by both ISO 14000 and BS 7750 standards). EN ISO 14001(1996) was adopted in the Czech Republic as a Czech norm CSN EN ISO 14001 in 1997.
Since this time an EMS has been implemented and certified in more than 30 companies by the Czech Norm CSN EN ISO 14001. These certifications were made mainly by international auditing companies such as Bureau Veritas Quality Int., RWTUV, TUV Reinland, and Lloyd’s Register Quality Assurance.

In 1999 the Czech Government decided to establish the “Czech National Eco-Management and Audit Scheme (EMAS) Program” taking into account the need to support implementation of EMS under EU Directive No. 1836/93 (EMAS). Two Czech companies were certified by EMAS (certification was registered in EU countries by international mother companies).

Lovochemie, Plc. is increasingly concerned with achieving and demonstrating sound environmental performance by controlling the impact of its activities, products, and services on the environment, while taking into account its environmental policy and objectives. The company does this in the context of increasingly stringent environmental legislation and a general growth of concern from interested parties about environmental issues on the local and regional scale and in the transboundary and international context, including aspects of sustainable development.

Lovochemie, Plc. has recently undertaken an initial environmental review to assess its environmental performance. To be effective, it was conducted within a structured management system and integrated with overall management activities. Some environmental aspects were incorporated into the QMS in our company. Practical experience has indicated the necessity to adopt an EMS throughout the company premises. This was the reason for starting preparation and implementation of an EMS in the company. As with most Czech companies, Lovochemie, Plc. decided to adopt international standard ISO 14000 for EMS certification. Steps undertaken to develop an EMS that were realized in Lovochemie include the following key ISO 14000 elements:

- Environmental policy.
- Environmental commitment from top management.
- Initial environmental review.
- Identification of environmental aspects.
- Environmental planning.
- Identification and documentation of legal and other requirements.
- Emergency preparedness.
- Environmental reporting and communication with third parties.
- Environmental training of employees.

A discussion of these key elements follows.

Environmental Policy and Top Management Commitment of Lovochemie, Plc.

The environmental policy is the driver for implementing and improving environmental management systems so that the EMS can maintain and improve the companies’ environmental performance. Senior management at Lovochemie, Plc. has defined environmental policy in the broader context of the environmental policy of the Unipetrol Group. This policy reflects the commitment to compliance with applicable environmental laws, principles of continual improvements, priority of preventive approach, emergency preparedness, and effective response. The environmental policy of Lovochemie, Plc. forms the basis upon which the company set the following objectives and targets:

- Reduce the production-related environmental impact to the level of EU limits by 2000.
- Finish remediation of environmental burdens from the past by 2000.
- Carry out modernization programs with the objective of reducing the environmental impact and improving production quality.
- Introduce training programs for employees with the objective of improving the sharing of environmental responsibility.

Approach to Obtaining EMS ISO 14000 Certification

The process of EMS preparation, implementation, and certification is like a long-distance run. To ensure success, an early step in developing an EMS involves a clear commitment by those at the highest level of management to improve environmental management of all activities in the company and all products and services. The commitment and leadership of management play a crucial role.

To achieve its environmental objectives a company has to focus and align its people, systems strategy, resources, and structure into the process. Other important elements are environmental awareness and motivation and support of senior management by employees through their knowledge, skills, and training. Senior management has a key role to play in building awareness and motivating employees by explaining company environmental values and communicating its commitment to the environmental policy. This commitment of individual people transforms an EMS from paperwork into an effective process.

An advantage of Lovochemie, Plc. was the experience that was obtained from the successful implementation of the QMS. Us-
able elements from the QMS experience include the following:

- Similarity of system QMS ISO 9002 and EMS ISO 14001.
- Upgrade of QMS ISO 9000 documentation to EMS ISO 14000 level.
- Experiences of the QMS ISO 9000 implementation process on how to motivate people and involve them in the process.
- Experiences of management and employee training.
- Experiences of the QMS ISO 9002 certification process.

**Initial Environmental Audit**—As the first step, an initial environmental review (audit) was conducted in 1998 by SCES Ltd., a consulting company. This audit and a detailed analysis of environmental aspects of Lovochemie production units included the following elements:

- Air pollution control.
- Water management.
- Soil protection.
- Transport of substances including raw materials and products.
- Health aspects of production.
- Monitoring of air pollution impact.
- Environmental law requirements.
- Register of raw materials, intermediates, and products.
- Handling raw materials, intermediates, and products.

Results of the initial environmental audit served to define priorities for investments, which included renovation of old facilities (storage facilities for calcium nitrate and compound NPK fertilizers), desulfurization of coal-fired boiler, stack gas, and emission reduction in the compound NPK fertilizer production unit.

An analysis of the environmental aspects of the production units made in 1998 consisted of an environmental assessment of energy generation, water treatment plant operation, nitric acid production and emission reduction, compound (NPK) fertilizer production and its impact on air and water pollution, and other key areas of production such as carboxymethylcellulose (LOVOSA), calcium ammonium nitrate, and finally liquid fertilizer urea-ammonium nitrate (LOVODAM and DAM 390).

**Environmental Achievements**

As a result of environmentally oriented activities in the field of emergency preparedness, Lovochemie, Plc. has been awarded, by the Czech Chemical Industry Association, the internationally recognized logo “Responsible Care."

In 1999 Lovochemie, Plc. achieved full legal compliance with all environmental health and safety requirements of the Czech laws. Two of the most important steps to improve the environment in the Lovosice region were a reduction of the air pollution impact of the production facilities, resulting in a significant improvement of air quality, and a substantial reduction in water demand.

An ongoing “air pollution monitoring program” is broadly accepted by state authorities and communities. An ongoing “remediation program for environmental burdens from the past” will reduce the impact of old burdens as they pertain to cross-boundary water pollution.

**Conclusion**

Lovochemie, Plc. introduced and certified QMS ISO 9002 for key production units during the period 1993-99. QMS ISO 9000 certification for other selected production units is expected in 2002 to finalize the process of QMS implementation and certification for all activities in the company. ISO 9002 certification has improved the position of the company in the domestic and the European market. Some products were awarded the high-quality mark “CZECH MADE.”

Lovochemie, Plc. is now in the process of implementing an EMS. Several important aspects of an EMS were adopted in Lovochemie, Plc., including environmental policy, environmental aspects analysis, initial environmental reviews, and an environmental program. The environmental program of the company is supported by environmental planning and investments. Certification of the EMS by ISO 14001 is expected by 2002.
Introduction

This paper describes in brief the experience of Abu Qir Fertilizers in qualifying for certification for both a Quality Management System according to the International Standards Organization (ISO) 9002 and an Environmental Management System according to ISO 14001. The paper discusses the approaches followed, constraints encountered, solutions proposed, and finally the benefits and advantages achieved.

It should be mentioned that the basic idea behind this paper is not to explain the environmental and quality standards because this is covered quite satisfactorily in many publications already available. The basic thrust of the paper is to provide Abu Qir’s own experience, focusing on the positive aspects and highlighting the areas of concern in implementing the two management systems. This paper may be a helpful tool to fertilizer-producing companies who decide to apply for the certification.

Company Profile

The Abu Qir Fertilizers Company is one of the largest nitrogen fertilizer production complexes in the Middle East. It was established in 1975 as a joint stock company. The company comprises three plants producing a total daily output of 6,000 mt. Pertinent data for each of the process plants are summarized in Table 1. Abu Qir Fertilizers dominates the domestic market with a market share of 70% and in addition has vast export potential to international markets. It employs 3,000 people and has paid capital of US $70 million and total assets of US $1 billion.

<table>
<thead>
<tr>
<th>Abu Qir Plant I</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia plant</td>
<td>1,100 mtpd</td>
</tr>
<tr>
<td>Urea plant</td>
<td>1,550 mtpd</td>
</tr>
<tr>
<td>Offsites and utilities</td>
<td></td>
</tr>
<tr>
<td>Process licenses</td>
<td>Krupp Uhde—ammonia</td>
</tr>
<tr>
<td></td>
<td>Stamicarbon—urea</td>
</tr>
<tr>
<td>Product</td>
<td>Prilled urea, 46.5% N</td>
</tr>
<tr>
<td>Date on stream</td>
<td>1979</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abu Qir Plant II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia plant</td>
</tr>
<tr>
<td>Nitric acid plant</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
</tr>
<tr>
<td>Process license</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Product</td>
</tr>
<tr>
<td>Date on stream</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abu Qir Plant III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia plant</td>
</tr>
<tr>
<td>Urea plant</td>
</tr>
<tr>
<td>Process licenses</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Product</td>
</tr>
<tr>
<td>Date onstream</td>
</tr>
</tbody>
</table>
Quality Management System (QMS)

Management’s Commitment to ISO 9002

Considering the tremendous advantages of applying a quality management system for a large company like Abu Qir, the decision was taken in mid-1995 to qualify for ISO 9002 certification. The Abu Qir senior management, after being fully convinced of the benefits that would be gained by implementing the system, played a very important role starting with the early phases of preparing the company for qualification. Abu Qir’s management positively adopted this objective, devoting the necessary technical, administrative, and financial resources to the support of those responsible for building the system.

Obtaining the certificate itself was not the only target. The real intention was to have an efficient, creative, and advanced tool to prepare the company to face the strong challenges and fierce competition of an open market.

Two parallel steps were considered during this phase. The first step was to form the Internal Audit Team, which was later called “The System Keepers.” Eventually, the proper and careful selection of the internal auditors in Abu Qir was, to a great extent, one of the very decisive elements behind our success in qualifying for the certificate. Continuous training was performed to upgrade their knowledge and skills.

Simultaneously, an extensive awareness program was conducted at all levels in the company, starting from the senior managerial level and reaching down to the lowest level in the hierarchical structure of the company.

Despite the extensive awareness programs conducted at all levels, backed by a full commitment and understanding of the company’s senior management to the importance of this issue, the quality team often encountered some “resistance” to the system by various department executives. It took time and effort until they finally realized that the system could be a “magic solution” to many of their chronic problems.

System Documentation and Implementation

For documenting the system procedures and work instructions, a simple but very practical approach was followed. The elements of the approach are given below:

1. Write what you do, then
2. Do what you wrote, but
3. Always keep the requirements of the ISO 9002 standards ahead of your eyes, accordingly
4. Correct, amend, and improve if and when necessary to cope with the standards, and finally
5. Avoid unnecessary complexity and write using your own language.

During the implementation phase, several internal audits were conducted in order to monitor and measure the efficiency of implementation. This was also a good opportunity for the internal audit team to practice on a “live basis.” Corrective and preventive actions taken during this phase have proved to add much to the stability and efficiency of the system.

The Certification Procedure

About 6 weeks before fixing the date for the certification audit, a preaudit, which is an optional and unofficial audit, was conducted. This preaudit was very helpful in giving a final impression about the performance of the quality system before the certification audit commenced.

It is highly recommended that the preaudit be carried out by the same certification body that will conduct the official audit. This enables the company to know the points of interest for the certification body, the areas of concern, weak points in the system, and the remedial measures to be taken.

Immediately after the preaudit was completed, a “crash program” was established to solve all the problems and cover the observations found during the preaudit. A task force formed by the quality team successfully executed this crash program.

Six weeks later, the certification audit was conducted, which demonstrated that the system was in full compliance with the requirements of the standards and that it was implemented very efficiently. Accordingly, the Quality Management System ISO 9002 certificate was issued on July 18, 1996, with a validity period of 3 years.

Effect of ISO 9002 on Abu Qir Fertilizers

The efficient implementation of the quality management system was, to a great extent, attributed to the management’s high degree of commitment and full understanding of the advantages that would be gained.

The system has become an essential part of the professional culture and daily behavior of every employee in Abu Qir and has led to significant improvements in the company’s overall financial performance as shown in Figures 1 and 2.

Environmental Management System (EMS)

ISO 14001: The Challenge of Implementation

As the environmental impact of modern industry becomes a major issue throughout the
world, organizations are working to systematically evaluate, manage, and minimize the environmental impact of their activities. Companies do not operate in isolation, and there are significant reasons for the heightened awareness of the importance of environmental protection, including international agreements leading to national environmental policy and legislation.

Rather than a constraint, environmental management is an opportunity that can:

- Ensure legal compliance as the trend of more stringent regulatory control continues.
- Identify cost benefits by identifying inefficient processes that have an impact on the environment.
- Increase sales through competitive advantage in the market by meeting the growing demands of the consumers.
- Meet the social and ethical responsibilities of the organization in today’s society.

All manufacturing companies are now looking at environmental management. A recent survey shows that the key motivator for environmental management is the sound business reason of financial cost saving rather than a simple compliance issue. Good business goes hand in hand with good environmental management.

In light of these factors and considering the very fruitful experience of Abu Qir in obtaining ISO 9002 certification, the company’s senior management decided in April 1998 to implement an Environmental Management System (EMS) according to the ISO 14001 and to prepare immediately for the qualification for certification.

Considering the complexity and high degree of sensitivity of
the technological processes for production of nitrogen fertilizers that are characterized by their broad spectrum of emissions to air, land, and water, it was a significant challenge for Abu Qir to proceed. On the other hand, the early and mature understanding of the importance of environmental issues at the managerial level, combined with a well-established environmental infrastructural base in Abu Qir, contributed positively to the decision.

Methodology

Integration With the Quality Management System ISO 9002

The first question that was raised early in the establishment of an environmental system was whether to build the EMS on an individual basis as a stand-alone project, or to make use of the advantages of the considerable commonality between the specifications of the Quality Management System ISO 9002 and the specifications of the Environmental Management System ISO 14001, and in this way build an integrated system. Considering its advantages, it was quickly decided to follow the latter alternative.

The Environmental Teams

Two working teams were given the responsibility of building and maintaining the EMS according to a prespecified scope of authorities and responsibilities. The first team was the Environmental Committee already formed about 8 years earlier; the second was the Quality and Environmental Group formed in 1995.

Members of the Environmental Committee are the heads of functional departments of the company that are involved in or have an influence on the environmental issues. This committee is authorized to deal with the environmental performance of the company at a rather strategic level. Members of the committee represent the following functional departments:

- Production.
- Utilities and offsites.
- Maintenance.
- Chemical labs.
- Environmental research and development (R&D).
- Management representative of the EMS.

The core of the Quality and Environmental Group was the quality assurance manager and the internal auditing team of the QMS. The quality auditing team was extended to include newly qualified auditors with knowledge and expertise in the environmental field. Extensive training in environmental and auditing techniques was provided to the auditors to prepare them for their tasks.

Additionally, every department in the company nominated one person to act as the Activity Coordinator and thus be the link between the department and the environmental team. Based on experience, this coordinator should be an active, dynamic, and talented personality in order to efficiently contribute to putting the department on the right environmental track. Contact between each activity coordinator and the head executive of his department with respect to all the system requirements is of primary importance.

Environmental Policy and Awareness

The establishment of an environmental policy mandated by top management is the first requirement for implementing an EMS. The environmental policy sets the stage for all the other elements of the company’s EMS. The policy establishes goals for environmental performance against which the effectiveness of the management system can be judged. Because the policy statement can have a significant impact on the company’s image, the following criteria were considered while establishing the Abu Qir Environmental Policy. The policy should:

- Reflect the moral and ethical basis for Abu Qir’s activities.
- Consider the nature of the company’s scope of activities, services, and products.
- Stress commitment to continuous improvement.
- Comply with the laws and relevant environmental legislation and regulations.
- Strive toward prevention and reduction of any adverse environmental impact resulting from its activity, thus supporting sustainable development.
- Be clear, concise, and implemented at all levels.
- Be available to the public.

Considering the above elements, the Abu Qir Environmental Policy was issued on September 1, 1998. It is important to stress here that top management is personally responsible to set the environmental policy of the organization as specifically mandated by the 14001 standards.

As part of the awareness program, the Abu Qir Environmental Policy was communicated at almost all levels by the following:

1. Publication and internal distribution of documents to all levels inside the company through the very efficient document control technique of the QMS.
2. Publication in the company’s annual reports and brochures made available to guests and interested third parties.
3. Publication on the internet on the company’s home page.
Identification of Environmental Aspects

Environmental aspects are those elements of an organization’s activities, products, services, or physical resources that may have potentially beneficial or harmful effects on the environment. These may include discharges and emissions, raw materials and energy use, waste recycling, noise, dust, and visual pollution.

An environmental impact is the change that takes place from the occurrence of any given aspect. The relationship between the two is causal—an impact is the pollution that can result if an environmental aspect is not properly managed or controlled.

Aspects involve technical concerns such as potential effects attributable to process, storage, transportation, utilities, and product. Impacts include emissions to air, water, soil and groundwater, hazardous wastes, energy use, material use, and nuisance concerns. Aspects are reviewed at the levels of site, plant, department, installation, and process. Complaints from third parties should be included in the development of a list of aspects.

It could be that some of the aspects are not regulatory requirements. As an example, waste production and energy consumption, although not regulated by set reductions or targets by government, are still aspects.

Aspect identification is important in that it is from this identification of the potential impact on the environment that the rest of the EMS system is built. When these various aspects are identified, they can then be properly managed. This is the basic intent of the entire ISO 14000 process; thus, thorough and complete identification of aspects is essential.

Identification of aspects is a continuous process under any EMS system. The aspect identification process includes all past, present and future impacts that an organization’s activities have had, are having, and will have on the environment. Included in this process, aside from the identification of regulatory requirements, should be an effort to identify the potential legal, financial, and business risks associated with all activities.

Abu Qir’s Approach to Aspect Identification

Recognizing the complexity of the task, given the numerous and varied functional departments in the company, including process, maintenance, utilities, workshops, financial, marketing, and administrative, the company determined a sequence of steps to be followed.

1. The direct environmental aspects resulting from Abu Qir’s various activities were generally classified as follows:

   | G | Gaseous emissions |
   | L | Liquid effluents  |
   | S | Solid wastes      |
   | D | Dust emission     |
   | N | Noise             |
   | LC| Land contamination|

   The indirect aspects were found to be:
   - Energy saving (power and fuels).
   - Conservation of resources (raw materials, natural gas, and chemicals).

2. Executives of every functional department listed the environmental aspects of their activities by applying the simple Black Box technique.

3. From step (2) above, all the aspects listed by the various departments were collected, verified, and duly recorded in the Environmental Aspects Register shown in Figure 3. This register shows all the information related to every aspect such as type, location, impact, symbol, department, and compliance with the legislation. Sixty-eight environmental aspects were listed in the register.

4. The contents of the Environmental Aspects Register were summarized and compressed into one single sheet called the Abu Qir Environmental Matrix (see Figure 4). This matrix and the environmental register were distributed to all departments. This allowed each department to easily recognize its own aspects as well as all the aspects of other departments.

5. The final, but most crucial step in this phase was to determine the “significance” of every environmental aspect included in the register. This was carried out by using an Aspects Evaluation Sheet (Figure 5). Of 68 aspects, 44 environmental aspects were classified as having “significant” impact, while the remaining 24 were found of no significance.

6. Among the various aspects assessed, some typical examples of the aspects related to the activities of a nitrogen fertilizer complex are shown in Table 2.

Setting the Objectives, Targets, and Environmental Programs

Following the identification of the environmental aspects of the Abu Qir complex and the classification of their impact into “significant” and “nonsignificant,” environmental objectives, targets, and environmental programs could then be determined.

Objectives were set to establish global and long-term concerns of
<table>
<thead>
<tr>
<th>Type of Aspect</th>
<th>Composition</th>
<th>Impact</th>
<th>Source of Emission</th>
<th>Aspect Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>Water Vapor</td>
<td>-</td>
<td>Cooling Tower Ammonia Plant</td>
<td>G2</td>
</tr>
<tr>
<td>Gas</td>
<td>CO₂</td>
<td>Air Pollution</td>
<td>Flue Gas Duct – Exhaust Stack</td>
<td>G3</td>
</tr>
<tr>
<td>Gas</td>
<td>CO₂ – H₂O</td>
<td>Air Pollution</td>
<td>CO₂ Removal Unit (Desorber)</td>
<td>G5</td>
</tr>
<tr>
<td>Gas</td>
<td>NH₃</td>
<td>Air Pollution</td>
<td>Leaks in Lines</td>
<td>G16</td>
</tr>
<tr>
<td>Dust</td>
<td>Urea</td>
<td>Air Pollution</td>
<td>Granulation Unit</td>
<td>D3</td>
</tr>
<tr>
<td>Solid</td>
<td>Spent Catalyst</td>
<td>Land Pollution</td>
<td>Process Plant</td>
<td>S13</td>
</tr>
<tr>
<td>Solid</td>
<td>Scrap</td>
<td>Waste of Resources</td>
<td>Different solid waste</td>
<td>S5</td>
</tr>
<tr>
<td>Liquid</td>
<td>Industrial Effluent</td>
<td>Sea Pollution</td>
<td>Water Treatment</td>
<td>L1</td>
</tr>
<tr>
<td>Liquid</td>
<td>Chemical Solutions</td>
<td>Sea Pollution</td>
<td>Chemical Labs</td>
<td>L2</td>
</tr>
<tr>
<td>Noise</td>
<td>Noise</td>
<td>-</td>
<td>Compressor House</td>
<td>N1</td>
</tr>
<tr>
<td>Oil Spills</td>
<td>Oil Spills</td>
<td>Land Contamination</td>
<td>Workshops – Storage – Others</td>
<td>LC</td>
</tr>
</tbody>
</table>

**Figure 3. Environmental Aspects Register (Example Only).**

---

<table>
<thead>
<tr>
<th>No. Activity</th>
<th>Air Emission</th>
<th>Solid Waste</th>
<th>Liquid Effluents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gas</td>
<td>Dust</td>
<td>Chemical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scrap</td>
<td>Others</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Others</td>
<td>Oils</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chemical Solution</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Others</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Noise</td>
</tr>
</tbody>
</table>

**Figure 4. Environmental Matrix.**
Environmental Aspects Evaluation Sheet (Example Only).

Table 2. Examples of Environmental Aspects of a Nitrogen Fertilizer Complex

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Gas</th>
<th>Dust</th>
<th>Solid</th>
<th>Liquid</th>
<th>Noise</th>
<th>Source of Emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flue gas duct, exhaust stack CO₂ removal units</td>
</tr>
<tr>
<td>NOₓ</td>
<td>■</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ammonia plants I, II, and III</td>
</tr>
<tr>
<td>CO₂+H₂O</td>
<td>■</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Absorption tower – Nitric acid plant</td>
</tr>
<tr>
<td>Urea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Flares plants I, II, and III</td>
</tr>
<tr>
<td>AN</td>
<td>■</td>
<td></td>
<td></td>
<td></td>
<td>■</td>
<td>Prilling tower and bagging plant Abu Qir I</td>
</tr>
<tr>
<td>Urea</td>
<td>■</td>
<td></td>
<td></td>
<td>■</td>
<td></td>
<td>Granulation and bagging plant Abu Qir II</td>
</tr>
<tr>
<td>Spent Catalyst</td>
<td>■</td>
<td></td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>Granulation and bagging plant Abu Qir III</td>
</tr>
<tr>
<td>Noise</td>
<td></td>
<td></td>
<td></td>
<td>■</td>
<td>■</td>
<td>Ammonia plants I, II, and III</td>
</tr>
<tr>
<td>Resins</td>
<td></td>
<td></td>
<td></td>
<td>■</td>
<td>■</td>
<td>Compressor houses I, II, and III</td>
</tr>
<tr>
<td>H₂O</td>
<td>■</td>
<td>■</td>
<td></td>
<td></td>
<td>■</td>
<td>Water treatment plants I, II, and III</td>
</tr>
<tr>
<td>CO₂</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td></td>
<td>Cooling towers I, II, and III</td>
</tr>
<tr>
<td>Plastic bags</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>Car workshops</td>
</tr>
<tr>
<td>Industrial water disposal</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>■</td>
<td>Bagging and loading I, II, and III</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>■</td>
<td>Water treatment plants I, II, and III</td>
</tr>
</tbody>
</table>

the organization about its environmental performance. For Abu Qir, four environmental objectives were fixed:

1. Recycling and reuse of industrial water effluents.
2. Safe disposal of effluents to the sea.
3. Safe disposal of solid wastes.
4. Reduction of air emissions and pollution prevention.

Environmental targets are more specific items that are usually derived from the objectives. An objective may result in one or several environmental target(s). Twelve environmental targets were identified for Abu Qir, and consequently twelve environmental programs were set up. In each environmental program, the following requirements were considered and fully met:

1. Fixed time frame for implementation and with activities identified.
2. Fixed budget allocation.
3. Defined resources.
4. Defined responsibilities and authorities.
5. Continuous monitoring and followup to measure the effectiveness of the program.

About US $3 million was allocated to finance the environmental programs for the fiscal year 1998/99.

The Preaudit

After about 7 months of effective implementation of the EMS and with the general impression that the system had sufficiently matured, a preaudit was conducted on the system performance. This preaudit was conducted by the same certification body that was selected to carry out the official audit at a later date.

During the preaudit, which lasted for 3 days, it was decided to make any information available to the audit team, giving the auditors free access to any location at the site of Abu Qir complex. Knowing the strong points in our system, which could be efficiently controlled, the company focused on showing the audit team the points that were considered weak points in the system.

The preaudit team identified 27 points of noncompliance. However, the degree of importance of the noncompliance observations varied widely from a very simple remark to notation of a significant nonconformity.

Immediately following the preaudit (the next day), a detailed and comprehensive rectification program was launched to resolve and eliminate all the observations found by the audit team. It took about 3 weeks to cover all the observations.

The Certification Audit

During the third week of April 1999, the official certification audit (initial audit) was carried out by Germanischer Lloyd, Hamburg. About 12 workdays were spent in performing the audit.

As was expected, the result was very successful in that the audit team could easily recognize the deep and effective implementation of the environmental management system in Abu Qir that had reflected positively on the company’s overall environmental performance.

In view of their findings, Germanischer Lloyd clearly concluded that Abu Qir Fertilizers was fully qualified to receive the ISO 14001 certification. Accordingly, it was decided to issue the certificate on April 15, 1999, in the name of the company with validity extending until April 2002. This also coincided with the successful renewal of the ISO 9002 certification for another 3 years.

Benefits

Abu Qir’s EMS is still relatively new, and thus it is too early for the company to assess all the benefits resulting from the implementation of the system. However, a summary of the benefits expected can be given.

Increased Profits—Increased profits are the most important of these benefits, which may be surprising for those unfamiliar with environmental management. Many companies recognize that pollution is also a cost because its components are purchased in raw materials. The ISO 14000 system can improve an existing EMS in many ways. One is the requirement that all employees in the company be knowledgeable about pollution prevention and their individual contributions. This draws on the efforts and creativity of everyone in the organization.

Customer Satisfaction—Establishing a strong environmental image will help attract environmentally conscious customers and provide an advantage over other competitors. A 1990 Gallup study found that 52% of the surveyed customers and investors stopped buying products with a poor environmental image.

Community Support—Community support to Abu Qir will be increased by demonstrating concern for the environment through an EMS. ISO 14001 adds to the credibility of an EMS because the company is certified by an independent auditor.

Compliance With the Laws—In Egypt there are many laws and regulations designed to protect the environment. They may carry financial and/or criminal penalties if not observed. The ISO 14000 series requires evidence of active procedures to maintain compliance with existing laws. These procedures can help identify areas of noncompliance and initiate action. Improved compliance with legislative and regulatory requirements could reduce penalties and remediation costs. Regulators may even favor companies with an ISO 14001 EMS.

Society—Finally, society in general benefits when companies reduce pollution with the help of the ISO 14000 series. Natural resources last longer because less of each resource is being used. Landfills receive less waste and thus remain usable longer. Air, water, and soil are cleaner. These benefits to society indirectly benefit the companies that are a part of it.
Workplace Monitoring and Occupational Health Studies at the Centre for Production of Phosphorus Mineral Fertilizer Using Nuclear and Related Analytical Techniques, Voskresensk (Moscow Region, Russia)

M. V. Frontasyeva,1,2 V. V. Golubchikov,3 A. V. Gorbunov,3 S. M. Lyapunov,3 O. I. Okina,3 T. L. Onischenko3

Abstract

The results are reported on monitoring the workplaces of the “Mineral Fertilizer” plant in Voskresensk (Moscow Region), one of the largest centers for production of phosphorus mineral fertilizer in Russia. Assessment of the present-day environmental situation for the main industrial premises of the plant is given. The most typical associations of element pollutants in the plant’s shops were determined by means of instrumental neutron activation analysis (INAA), atomic absorption spectroscopy (AAS), and energy disperse X-ray fluorescence spectroscopy (XRFA). The maximal pollution by dust particulates and the highest concentrations for Na, Ca, Sc, Cr, Fe, As, Sb, Sr, rare earth elements (REE), and Th at the loading-unloading sites of the shops were revealed. The total dust impact on biosubstrates of the occupational staff (hair and urine) was examined. The level of trace element concentrations in the biosubstrates reflects the sustained and systematic impact of air pollutants in the working area of the plant. The results on assessing the present-day environmental situation in the vicinity of the “Mineral Fertilizer” plant are given. It is shown that F, Sr, and REE produce the most intensive impact on the occupational staff and local residents. The effect of agricultural use of mineral fertilizer byproducts—compost and phosphogypsum—on trace elements in soils and vegetation was examined.

Scientific Background and Scope of the Study

Nitrophosphate mineral fertilizer production is one of the very few branches of industry in the Russian Federation that was only slightly affected by the economic collapse of the 1990s. As it was shown in previous studies [1-3], fertilizer production is characterized by a significant impact on the occupational staff, local residents, and the environment. The mentioned investigations were rather fragmented and were dedicated either to selected groups of elements [1,4] or to selected objects affected by fertilizers or by their byproducts [5,6]. It is evident, however, that the effect of fertilizer production is very complex, and it should be studied on a large scale, taking into consideration the whole variability of the affected objects for a greater number of chemical elements.

Table 1 contains data on the elemental content of main components of the technological chain of the mineral fertilizer plant in Voskresensk. The analysis of these data shows that in the process of ammophos (ammonium phosphate) production concentrations of such elements as F, Sr, Sb, and REE decrease. The most probable technological operations responsible for the loss of these components are the vacuum evaporation when extracting oleum phosphate, the drying of ammophos, and co-precipitation of phosphogypsum. The main emissions are emitted into the atmosphere and discharged into the sewage waters. The above analysis allows one to list the following tasks that were solved in our study:

1. The investigation of the main transporting and depositing natural media (air, water, and soil) for determining the distribution of element pollutants in the emissions of the plant.
2. The investigation of the distribution of element pollutants in the main diagnostic human biosubstrates (hair, bone tissue, and urine) aimed to determine how man’s biosubstrates can be

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used to follow the rate of pathological changes in the organism of the occupational staff and local residents when exposed to intense technogenic environments.

3. The investigation of the possibility to use the industrial byproducts (compost from the sewage tanks and phosphogypsum) in agriculture aimed to minimize the damage to the environment produced by a given plant.

To solve these tasks, it was necessary to collect and analyze atmospheric aerosol samples from all working shops of the plant and beyond the premises of the plant. The sewage waters of the plant, water, and bottom sediments of the Moscow River and soil samples at the premises of the plant also had to be examined. Besides, it was necessary to collect diagnostic biosubstrates of the occupational staff and local residents of the town of Voskresensk. To complete the picture, it was also necessary to arrange and conduct experiments on the use of the main byproducts of the plant—compost from the sewage tanks and phosphogypsum—in agriculture.

### Experimental

#### Atmospheric Aerosols

Atmospheric aerosols and pollution streams (dust) emitted into the air were collected in the shops of oleum phosphate extraction (OPE-1,3,4), ammonium phosphate fertilizer production (AMM-1,2), oleum sulfate extraction (OSE-3), and in the Central laboratory of the plant (CL). Samples were collected in the places of permanent or long-term work of the occupational staff. To determine fluorine in air samples, a technique based on a bubbling process was used [7-9]. To collect aerosols on filters (AFA-XA-20, Russia), electric aspirators (model 228 and AC-1, Russia) were used continuously during the working time (6-8 h) to pump about 0.6 ± 5 m³ of air sample.

To estimate the most probable sources of the air pollution in the work area, samples of the main type of industrial raw material (apatite concentrate), the final product ammonium phosphate (ammophos), and its byproducts (phosphogypsum and compost) were collected.

To assess the distribution of pollutants in air flows in the vicinity of the acting emission source, snow as a depositing medium has been used. Snow sampling is significantly cheaper and less labor consuming than collecting of atmospheric aerosols by means of impactors. Besides, snow sampling gives an integral picture of atmospheric pollution levels for the period of permanent snow cover in winter months, and it is considered one of the most comparative and complete sources of information characterizing both the aerosol and gaseous components of at-

<table>
<thead>
<tr>
<th>Type</th>
<th>F (%)</th>
<th>Na (%)</th>
<th>P₂O₅ (%)</th>
<th>Ca (%)</th>
<th>Sc (%)</th>
<th>Ti (%)</th>
<th>Cr (%)</th>
<th>Mn (%)</th>
<th>Fe (%)</th>
<th>Co (%)</th>
<th>Cu (%)</th>
<th>Zn (%)</th>
<th>As (%)</th>
<th>Br (%)</th>
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<td>&lt;10</td>
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<td>18</td>
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<td>-</td>
<td>320</td>
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<table>
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<tr>
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<th>Y (%)</th>
<th>Zr (%)</th>
<th>Nb (%)</th>
<th>Sb (%)</th>
<th>Ba (%)</th>
<th>La (%)</th>
<th>Ce (%)</th>
<th>Sm (%)</th>
<th>Au (%)</th>
<th>Th (%)</th>
<th>U (%)</th>
<th>Pb (%)</th>
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<td>8.7</td>
<td>800</td>
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</tr>
<tr>
<td>Phosphogypsum</td>
<td>&lt;5</td>
<td>1.4</td>
<td>190</td>
<td>380</td>
<td>&lt;20</td>
<td>&lt;1</td>
<td>1,550</td>
<td>1,000</td>
<td>1,400</td>
<td>80</td>
<td>&lt;0.05</td>
<td>60</td>
<td>10</td>
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</tr>
<tr>
<td>Compost</td>
<td>46</td>
<td>0.14</td>
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<td>8.6</td>
<td>500</td>
<td>40</td>
<td>65</td>
<td>7.9</td>
<td>&lt;0.05</td>
<td>3.1</td>
<td>3.0</td>
<td>50</td>
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mospheric pollution. The snow sampling was carried out in accordance with the wind-rose from the seven experimental sites along the profile A-B-C, crossing the village of Saburovo, the mineral fertilizer plant (1), town of Voskresensk, the village of Lopatino (3), the Lopatinsky carrier (4), the “Phosphate” enterprise (5), and the village of Ostashevo (6). The profile is directed from the South-East to North-East; its length is about 15 km (Figure 1).

The sampling was carried out at representative experimental sites of 500X500 m². No less than seven samples were collected at each site. The background area was situated at a distance of 20 km from the plant where its technogenic impact is almost absent, as one may assume. The snow samples were collected at the end of March, i.e., after 5.5 months of permanent snow cover. Sampling was carried out from the core, starting from the total depth of the snow cover. The volume of the snow core was fixed. The samples were packed in double polyethylene bags and brought to the laboratory for further processing, which included (1) melting at room temperature, (2) filtration of snow through a dense filter, and (3) drying and weighing the undissolved residual on the filter. Filters with the undissolved residual and liquid filtrate were subjected to cation-anion analysis.

**Soil**

The technogenic anomalies in soil as usual are sufficiently less intensive than in the atmospheric air or in the snow cover. Nevertheless, the soil contamination is an important characteristic of the plant emissions, assuming its multiyear technogenic impact. Soil samples of the upper (0-3)+(0-10) cm humus horizon were collected in the central and eastern parts of the territory in accordance with norms and standards accepted in the Russian Federation [10-11].

**Industrial Sewage, Water, and Bottom Sediments**

Industrial sewage is a hazardous source of pollution of natural water resources. The sewage emission of the plant can be subdivided into conditionally clean, economic everyday (domestic), and chemically polluted. The conditionally clean waters, i.e., 80% of all sewage emissions, are discharged directly into the Moscow River through the western and central collectors. The economic everyday (domestic) and chemically polluted sewage is passing to the sewage tanks where it is also neutralized.

Water samples were taken directly from the collector and from the Moscow River upstream and downstream of the collector. The whole procedure—sample collecting, conservation of water, and its storage—were performed in accordance with norms and standards approved by the Russian Federation [12-13]. Bottom sediments were collected along the banks of the Moscow River at a depth of 1-1.5 m at intervals of 500 m (Figure 2).

**Biosubstrates**

To assess the effect of a chemical element on an organism, one needs to know its concentration in the diagnostic media (biosubstrates) of man. Blood, urine, nails, and hair are usually used for such purposes of studying the anthropogenic impact on the environment. Sometimes when studying the multyear effects, bone tissue (teeth) is used. In this study, the labor-consuming and costly blood analyses were omitted. The biosubstrates were collected from the occupational staff of the main shops of the mineral fertilizer plant, from the local residents (adults) of the adjacent districts, and from the kindergarten children of the town of Voskresensk. Samples of hair were collected in accordance with the scheme illustrated by Di Pietro et al. [14]. Samples of bone tissue (teeth) were obtained for the analysis from the polyclinic of the plant.

**Agricultural Experiments With the Industrial Byproducts**

One of the main problems of mineral fertilizer production is the disposal of its byproducts.
There were several attempts to introduce these byproducts into agricultural systems. According to some references, these byproducts allow one to increase the crop capacity of soybean and maize for silo and lucerne by 1.5-2 times [5]. However, all these studies had one and the same defect—they absolutely ignored the accumulation of chemical elements in soils and agricultural products. We have undertaken two experiments to examine to what degree the compost from sewage tanks and phosphogypsum introduced as meliorant affect the quality of soils and agricultural vegetation.

**Introduction of Compost From the Sewage Tanks of the Plant to Agriculture**—Experiments with acidic (pH 4-6) soddy podzolic soils of the Moscow Region were carried out. The essence of the experiments was as follows: under equal (control) conditions to the squares where salad greens were growing, different amounts of compost were introduced. Doses introduced were 0.4, 0.8, 1.3, and 1.9 kg/m². The experiment lasted for 1.5-2 months. The live weight of vegetation and the accumulation of chemical elements in soils and vegetation were determined.

**Introduction of Phosphogypsum to Agriculture**—As a result of the oleum sulfate extraction process (most common in the production of phosphorus fertilizers), 5 tons of phosphogypsum are precipitated per 1 ton of the final product (P₂O₅). This provides 1.7 x 10⁸ tons per year of phosphogypsum if calculated for the world’s production of P₂O₅. On the other hand, there is a big problem in recultivating the saline soils for agriculture. It is commonly recognized that the introduction of phosphogypsum to these saline soils is the most effective means of desalination.

Experiments with alkali light chestnut and saline soils in the conditions of the arid climate of the Volgograd Region lasted for 2 years. The application rate of phosphogypsum introduced was 10 tons/ha in the upper soil horizon at the beginning of the season. Soil samples were also collected from the upper horizon (0-20 cm). During the first year vegetation was not sown; during the second year a harvest of *sudan grass* was collected. Soils and vegetation of the second year’s experiment were subjected to the chemical analysis.

**Analytical Methods**—The element concentrations of the collected samples were determined by means of instrumental neutron activation analysis (INAA), atomic absorption spectroscopy (AAS) and energy disperse X-ray fluorescence spectroscopy (XRFA), and by the ion-selective method in the laboratories of the Geological Institute of RAS, Moscow, and JINR, Dubna. The analyses were carried out according to standard methods described elsewhere [15-18]. The quality assurance was provided by using national and international standard reference materials (SRMs).

**Results and Discussion**

Table 2 contains data on concentrations of trace elements in air on the premises of the mineral fertilizer plant, six shops, and the Central laboratory. The analysis showed that:

- The fluorine content in air of the shops of oleum phosphate extraction is near the maximum permissible levels.
The concentration of other elements in the air of workplaces does not exceed the maximum permissible levels in any shop.

Maximum air pollution with airborne particulate matter and the maximum concentrations of Na, Ca, Sc, Cr, Fe, As, Sb, Sr, rare earth elements (REE), and Th occur at the loading-unloading sites.

Relatively high levels (but not exceeding the maximum permissible) of As were observed in the air of the Central laboratory premises.

The concentrations of soluble compounds in snow water are demonstrated in Figure 3. The data evidence of fluorine, chlorine, ammonium nitrate, sulfur oxide and phosphorus in the examined air above the snow cover. The abnormally high concentrations of fluoride and sulfur oxides are characteristic for the premises of mineral fertilizer plants. The fluoride ion concentration exceeds the background value by a factor of 60, as it is demonstrated in Figure 3.

The results of the analysis of snow dust are given in Table 4.

Table 3. Cation-Anion Content in the Liquid Phase of Snow Samples, mg/L

<table>
<thead>
<tr>
<th>No.</th>
<th>Sampling Site No.</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Ca²⁺</th>
<th>Mg²⁺</th>
<th>NH₄⁺</th>
<th>HCO₃⁻</th>
<th>SO₄²⁻</th>
<th>F⁻</th>
<th>Cl⁻</th>
<th>PO₃³⁻</th>
<th>NO₃⁻</th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2.2</td>
<td>3.7</td>
<td>51</td>
<td>4.8</td>
<td>0.8</td>
<td>70</td>
<td>43.0</td>
<td>1.1</td>
<td>6.8</td>
<td>0.7</td>
<td>2.1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1.2</td>
<td>2.0</td>
<td>28</td>
<td>6.4</td>
<td>1.4</td>
<td>58</td>
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<td>5.6</td>
<td>0.2</td>
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<td>3</td>
<td>0.6</td>
<td>1.2</td>
<td>20</td>
<td>1.9</td>
<td>1.2</td>
<td>54</td>
<td>10.0</td>
<td>0.3</td>
<td>4.8</td>
<td>0.2</td>
<td>1.1</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>0.2</td>
<td>0.8</td>
<td>16</td>
<td>2.0</td>
<td>0.9</td>
<td>52</td>
<td>9.6</td>
<td>0.2</td>
<td>5.8</td>
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<td>5</td>
<td>5</td>
<td>0.4</td>
<td>0.5</td>
<td>14</td>
<td>1.8</td>
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<td>32</td>
<td>6.4</td>
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<td>6</td>
<td>6</td>
<td>0.5</td>
<td>0.3</td>
<td>12</td>
<td>1.6</td>
<td>1.0</td>
<td>33</td>
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<td>7</td>
<td>0.6</td>
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<td>20</td>
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<td>1.8</td>
<td>55</td>
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<td>Background</td>
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<td>1.7</td>
<td>1.2</td>
<td>40</td>
<td>4.2</td>
<td>0.02</td>
<td>4.9</td>
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</table>
These data show that the pollutants could be subdivided into two groups according to the different behavior of their distributions along the profile. Such elements as Sr, Y, REE, and Th are referred to as the first group. The distribution of these elements along the profile is nearly identical to that of fluoride (Figures 3 and 4) and is connected with the activity of the plant. Antimony and lead are related to the second group. Their distribution by no means is connected with the mineral fertilizer plant, which is confirmed by the minimal concentrations of these elements at the industrial premises of the plant.

Table 5 contains data on the trace-element content in the humus soil horizon at the premises of the plant. Soil is a complex organic-mineral system where the process of accumulation of element pollutants competes with the process of their leaching. Data in Table 5 show that soil at the premises of the plant is characterized by abnormally high concentrations of F, Cu, Zn, As, Sr, and REE. The concentration of F, Cu, and Zn exceeds the background values by a factor of 7-8, for other elements—of 3-4.

The Moscow River in the vicinity of the town of Voskresensk absorbs emissions of the town and its numerous enterprises. Besides, upstream of the flow, it is influenced by the Moscow City agglomeration. Therefore, the quality of water near Voskresensk differs greatly from clean, unpolluted waters. The content of sewage water from the mineral fertilizer plant and of water from the Moscow River (taken for the single analysis during floods) is given in Table 6. The peculiarities of the trace element content of sewage waters from the plant, in particular, the elevated content of sulfates, phosphates, fluorine, copper, and zinc allows one to conclude that the plant is potentially hazardous to the Moscow River waters. However, the results given in the same table on water analy-
sis from the Moscow River show that this effect is almost negligible.

The bottom sediments represent the most informative medium, which fixes the multiyear impact of the pollution source on the given aquatic system. The composition of the bottom sediments reflects the imperfection of the water purification system not only at present but also in earlier periods of the plant’s activity. Besides, bottom sediments could be the source of the secondary pollution of the surface waters.

Bottom sediments collected at the sites shown in Figure 2 are silt, silt-sand, or silt-clay deposits. Their mineral content is given in Table 7. The association of chemical elements is rather representative, but the element concentrations are relatively low, except for samples 7 and 8, which were collected in the direct vicinity of the central sewage emissions of the plant. High concentrations of Co, Cu, Zn, As, Pb, Sr, REE in the bottom sediments and their absence in the sewage waters is evidence for the imperfection of the water puri-

### Table 5. Trace-Element Content in Soil at the Mineral Fertilizer Plant Premises, mg/kg

| Object                  | F  | Na | K  | Sc | Cr | Fe | Co | Cu | Zn | As | Br | Sr | Sb | La | Ce | Sm | Th | Pb |
|-------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Plant premises          | 2.50 | 2.800 | 7,000 | 3.1 | 48 | 16,500 | 4.9 | 290 | 930 | 20 | 3.3 | 390 | 0.6 | 35 | 74 | 6.1 | 4.0 | 130 |
| Background              | 310 | 3,000 | 10,000 | 3.0 | 39 | 9,600 | 5.0 | 41 | 130 | 4.7 | 2.5 | 100 | 0.6 | 14 | 25 | 2.8 | 3.4 | 40 |

### Table 6. Trace-Element Content in Sewage Waters and in Its Suspension at the Mineral Fertilizer Plant

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<th>Sampling site</th>
<th>SO₄²⁻</th>
<th>HCO₃⁻</th>
<th>NO₃⁻</th>
<th>NO₂⁻</th>
<th>NH₄⁺</th>
<th>PO₄³⁻</th>
<th>F</th>
<th>Cl</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Cu²⁺</th>
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<td>140</td>
<td>5.0</td>
<td>&lt;0.05</td>
<td>0.6</td>
<td>1.5</td>
<td>1.8</td>
<td>50</td>
<td>41</td>
<td>8.0</td>
<td>95</td>
<td>15</td>
<td>&lt;1</td>
<td>5.0</td>
<td>53</td>
<td>18</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Western discharge</td>
<td>900</td>
<td>160</td>
<td>13</td>
<td>&lt;0.05</td>
<td>1.0</td>
<td>3.4</td>
<td>9.0</td>
<td>96</td>
<td>37</td>
<td>6.0</td>
<td>78</td>
<td>12</td>
<td>&lt;1</td>
<td>3.8</td>
<td>22</td>
<td>9.0</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>Moscow River, lower than the plant</td>
<td>30</td>
<td>150</td>
<td>12</td>
<td>&lt;0.05</td>
<td>0.2</td>
<td>3.4</td>
<td>0.4</td>
<td>57</td>
<td>33</td>
<td>6.0</td>
<td>60</td>
<td>12</td>
<td>&lt;1</td>
<td>3.0</td>
<td>31</td>
<td>2.2</td>
<td>9.1</td>
<td></td>
</tr>
<tr>
<td>Moscow River, higher than the plant</td>
<td>30</td>
<td>150</td>
<td>7.0</td>
<td>&lt;0.05</td>
<td>0.2</td>
<td>3.4</td>
<td>0.4</td>
<td>57</td>
<td>33</td>
<td>6.0</td>
<td>64</td>
<td>12</td>
<td>&lt;1</td>
<td>2.8</td>
<td>20</td>
<td>2.0</td>
<td>6.0</td>
<td></td>
</tr>
</tbody>
</table>

### Table 7. Trace-Element Content in Bottom Sediments of the Moscow River, mg/kg

<table>
<thead>
<tr>
<th>Sample</th>
<th>Sc</th>
<th>Cr</th>
<th>Co</th>
<th>Cu</th>
<th>Zn</th>
<th>As</th>
<th>Sr</th>
<th>Y</th>
<th>Sb</th>
<th>La</th>
<th>Ce</th>
<th>Sm</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.5</td>
<td>40</td>
<td>8.4</td>
<td>70</td>
<td>50</td>
<td>8.4</td>
<td>90</td>
<td>20</td>
<td>0.9</td>
<td>28</td>
<td>59</td>
<td>4.6</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>7.0</td>
<td>52</td>
<td>0.15</td>
<td>70</td>
<td>40</td>
<td>6.0</td>
<td>60</td>
<td>10</td>
<td>0.4</td>
<td>27</td>
<td>59</td>
<td>5.3</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>4.7</td>
<td>45</td>
<td>6.4</td>
<td>70</td>
<td>80</td>
<td>9.6</td>
<td>100</td>
<td>20</td>
<td>0.6</td>
<td>20</td>
<td>41</td>
<td>3.5</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>100</td>
<td>18</td>
<td>70</td>
<td>290</td>
<td>23.0</td>
<td>150</td>
<td>30</td>
<td>1.4</td>
<td>39</td>
<td>79</td>
<td>7.9</td>
<td>70</td>
</tr>
<tr>
<td>5</td>
<td>3.0</td>
<td>57</td>
<td>4.3</td>
<td>70</td>
<td>120</td>
<td>7.9</td>
<td>100</td>
<td>20</td>
<td>0.5</td>
<td>28</td>
<td>57</td>
<td>4.8</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>2.3</td>
<td>32</td>
<td>4.8</td>
<td>70</td>
<td>70</td>
<td>12.0</td>
<td>60</td>
<td>10</td>
<td>1.0</td>
<td>17</td>
<td>34</td>
<td>2.5</td>
<td>30</td>
</tr>
<tr>
<td>7</td>
<td>4.0</td>
<td>73</td>
<td>38</td>
<td>660</td>
<td>960</td>
<td>1,900</td>
<td>170</td>
<td>50</td>
<td>84</td>
<td>15</td>
<td>36</td>
<td>2.1</td>
<td>3,900</td>
</tr>
<tr>
<td>8</td>
<td>6.0</td>
<td>66</td>
<td>17</td>
<td>80</td>
<td>230</td>
<td>33.0</td>
<td>300</td>
<td>20</td>
<td>1.9</td>
<td>67</td>
<td>110</td>
<td>7.6</td>
<td>60</td>
</tr>
<tr>
<td>9</td>
<td>3.6</td>
<td>43</td>
<td>6.3</td>
<td>70</td>
<td>70</td>
<td>11.0</td>
<td>100</td>
<td>10</td>
<td>0.7</td>
<td>32</td>
<td>63</td>
<td>5.6</td>
<td>30</td>
</tr>
<tr>
<td>10</td>
<td>3.7</td>
<td>41</td>
<td>7.9</td>
<td>70</td>
<td>50</td>
<td>16.0</td>
<td>100</td>
<td>20</td>
<td>0.7</td>
<td>23</td>
<td>50</td>
<td>5.1</td>
<td>40</td>
</tr>
<tr>
<td>11</td>
<td>10</td>
<td>42</td>
<td>13</td>
<td>70</td>
<td>80</td>
<td>42.0</td>
<td>270</td>
<td>20</td>
<td>0.8</td>
<td>26</td>
<td>45</td>
<td>4.8</td>
<td>30</td>
</tr>
<tr>
<td>12</td>
<td>7.3</td>
<td>58</td>
<td>12</td>
<td>90</td>
<td>320</td>
<td>17.0</td>
<td>140</td>
<td>30</td>
<td>0.8</td>
<td>40</td>
<td>87</td>
<td>9.0</td>
<td>40</td>
</tr>
<tr>
<td>Background</td>
<td>1.7</td>
<td>19</td>
<td>3.4</td>
<td>35</td>
<td>40</td>
<td>4.0</td>
<td>23</td>
<td>10</td>
<td>0.3</td>
<td>5.7</td>
<td>11</td>
<td>1.0</td>
<td>12</td>
</tr>
</tbody>
</table>
The trace-element content of the occupational staff hair is given in Table 8. In general, the biochemical association of trace elements fully corresponds to its atmochemical base.

The results obtained show that:

- Hair of the occupational staff contains high concentrations of F, REE, and Sb.
- The highest level of these elements is observed at the oleum phosphate extraction shop.
- This impact has a distinct gradation for the staff professions. The highest concentrations of fluorine in hair correspond to the lowest REE concentrations, and vice versa. The correlation coefficient for fluorine and REE is -0.7. The greatest impact of fluorine on the occupational staff takes place in the sites of the vacuum evaporation section of the plant. The REE maximal impact on the occupational staff takes place at the unloading sites.
- In the shops involved in ammonium phosphate production, the level of element-pollutants impact is significantly lower. The most hazardous is the site for ammophos drying.
- The Central laboratory site is characterized by an insignificant increase in REE content in hair of the occupational staff.

It is evident that the most hazardous of all of the above-mentioned elements is fluorine, which is the most active natural oxidizer belonging to the I group of toxicants [19]. As for REE, their presence is shown in almost all biological objects [6, 20, 21], but their biological role is not quite clear until now.

The fluorine content in hair allows one to estimate its impact on man. At present, there is no physiologically motivated maximum permissible level for fluorine content in hair. However these levels exist for other biosubstrates, for urine, in particular [19].

The results on fluorine content in teeth and urine of the occupational staff of the plant and on local residents, living in the vicinity of the plant, are given in Table 9. The data show that:

- The fluorine content in teeth practically reproduces the analogous data for hair.
- The maximum content of fluorine in urine of the occupational staff exceeds background values by a factor of 8.
- Even for children living in the vicinity of the plant, the fluorine content in urine exceeds the background values by a factor of 3.

It is known that the fluorine content in urine at the level of 3.3 mg/L and higher may cause *fluorosis* or different hardness [19, 21, 23].

The fluorine content in urine at the level of 2-3.3 mg/L leads to dysfunction of the cardiovascular system and the liver, and causes osteoporosis. The level lower than 2 mg/L corresponds to an almost healthy population. It is evident that the occupational staff of the plant and even some of the local residents of the town of Voskresensk belong to the group at increased health risk with regard to the above-mentioned dysfunction.

The results on the agricultural experiment with compost from sewage tanks are given in Table 8.
Table 10. One should note that the salad yield capacity increased by a factor of 1.4-1.6 at the maximal introduction doses of compost. Data given in Table 10 show that the accumulation of almost all trace elements in soil takes place. Thus, for example, the concentration of Cr exceeds background values by 10 times and Fe, As, and Sb by 3-4 times. The concentration of bromine is an exclusion; it became lower than the background level.

Trace-element accumulation takes place in vegetation also. First of all, one should note the increased concentrations of As and Sb, which approach the maximum permissible levels (0.3 mg/kg) for food products. Besides, trace-element accumulation in soil differs from that in vegetation. To better understand the character of this accumulation, we calculated the coefficients of accumulation of trace elements in vegetation:

\[ K_a = \frac{C_v}{C_s}, \]

where

\[ K_a \]

is the coefficient of accumulation of a given element in vegetation;

\[ C_v \]

is its concentration in vegetation;

\[ C_s \]

is its concentration in soil.

Table 9. Fluorine Content in the Teeth (mg/kg) and Urine (mg/L) of the Occupational Staff and Local Residents from the Vicinity of the Mineral Fertilizer Plant

<table>
<thead>
<tr>
<th>Object of Investigation</th>
<th>Teeth (n=16)</th>
<th>Urine (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupational staff having contact with fluorine</td>
<td>730</td>
<td>4.1</td>
</tr>
<tr>
<td>Occupational staff having no contact with fluorine</td>
<td>72</td>
<td>2.3</td>
</tr>
<tr>
<td>Adults</td>
<td>not determined</td>
<td>2.1</td>
</tr>
<tr>
<td>Children</td>
<td>not determined</td>
<td>1.8</td>
</tr>
<tr>
<td>Physiologically admissible level</td>
<td>not determined</td>
<td>1.0</td>
</tr>
<tr>
<td>Background</td>
<td>50</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 10. Content of Chemical Elements in Soil and Salad Leaves Relative to the Introduced Amount of Compost, mg/kg

<table>
<thead>
<tr>
<th>Object</th>
<th>Introduced Amount of Compost, kg/m²</th>
<th>Na (%)</th>
<th>K (%)</th>
<th>Ca (%)</th>
<th>Sc</th>
<th>Cr</th>
<th>Fe (%)</th>
<th>Co</th>
<th>As</th>
<th>Br</th>
<th>Sb</th>
<th>La</th>
<th>Ce</th>
<th>Sm</th>
<th>Th</th>
<th>U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>Background</td>
<td>0.30</td>
<td>0.27</td>
<td>0.32</td>
<td>0.9</td>
<td>0.9</td>
<td>0.8</td>
<td>0.6</td>
<td>0.9</td>
<td>0.1</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>0.36</td>
<td>0.40</td>
<td>0.60</td>
<td>0.6</td>
<td>1.1</td>
<td>0.8</td>
<td>1.1</td>
<td>1.1</td>
<td>0.9</td>
<td>3.4</td>
<td>0.8</td>
<td>0.9</td>
<td>0.6</td>
<td>0.2</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>0.8</td>
<td>0.36</td>
<td>0.40</td>
<td>0.60</td>
<td>0.6</td>
<td>1.1</td>
<td>0.8</td>
<td>1.1</td>
<td>1.1</td>
<td>0.9</td>
<td>3.4</td>
<td>0.8</td>
<td>0.9</td>
<td>0.6</td>
<td>0.2</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>0.6</td>
<td>1.1</td>
<td>1.4</td>
<td>6.6</td>
<td>160</td>
<td>3.0</td>
<td>11</td>
<td>11</td>
<td>2.5</td>
<td>3.7</td>
<td>3.0</td>
<td>0.3</td>
<td>0.9</td>
<td>0.25</td>
<td>0.3</td>
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<tr>
<td></td>
<td>1.9</td>
<td>0.9</td>
<td>1.6</td>
<td>1.6</td>
<td>10.4</td>
<td>300</td>
<td>3.8</td>
<td>11</td>
<td>11</td>
<td>2.5</td>
<td>3.7</td>
<td>3.0</td>
<td>0.3</td>
<td>0.9</td>
<td>0.25</td>
<td>0.3</td>
</tr>
<tr>
<td>Salad</td>
<td>Background</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>1.0</td>
<td>1.0</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>0.8</td>
<td>1.0</td>
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<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
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<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
<td>2.1</td>
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<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
</tr>
</tbody>
</table>
The dependencies of coefficients of accumulation of the main trace elements in salad leaves on introduction doses of compost are demonstrated in Figure 5. It is evident that the maximum accumulation of Na, K, Fe, Cr, and of some other important elements for the growth of the plant corresponds to the introduction dose of compost of 0.8 kg/m². A further increase of the dose leads to a decrease of trace-element accumulation. This does not refer to As; unfortunately, so far its accumulation grows continuously with the increase of the introduction dose.

From the above, we note that:

- The accumulation of trace elements takes place in soil.
- The concentrations of As and Sb in salad leaves reach values close to the maximum permissible levels for these elements.
- The maximum crop capacity (alive mass of the vegetation) is achieved at the introduction dose of compost of 1.9 kg/m², whereas the relative depletion of such trace elements as Na, K, Ca, Fe, and Cr takes place.

One may conclude that it is unreasonable to apply compost from the plant sewage tank for agricultural use.

Table 11 contains data on the experiment with application of phosphogypsum (CaSO₄ + 2H₂ + 1.4% P₂O₅) to saline soils of the Volgograd Region. The saline soils are characterized by a relatively high level of accumulation of major and trace elements. It is evident from data given in Table 11 that ecologically hazardous elements are F, S, As, Sr, and Sb. The impact of REE on the environment is less studied, but in principle due to their specific physical and chemical features, they may cause unpredictable changes in the mobility of toxic chemical elements found in soils.

The results of the analysis show that:

- Such chemical elements as F, Na, S, As, Br, Sb, and Th demonstrate the tendency for leaching. Their concentrations in the results of the experiment have minimum values for both types of soils.
- P, K, Fe, Sr, and REE have the opposite tendency to accumulate in soils.
- In *sudan grass* some accumulation of P, K, Cu, and REE is observed and some depletion in Na, Co, and Br, while the general grass capacity increases by a factor of 1.5-2.

Thus, assuming the above, one can state that the agrochemical processing of saline complex soils by phosphogypsum is a positive and a potential means of amelioration.

**Conclusions and Summary**

1. Nitrophosphate mineral fertilizer production is the source of emissions of F, Ca, Sr, and REE to the environment.
2. These chemical elements are mainly emitted into the atmosphere.
3. No impact of the mineral fertilizer plant on the quality of water in the Moscow River was observed.
4. Elevated concentrations of F and REE are observed in biosubstrates of the occupational staff.
5. The agricultural use of compost from sewage tanks has no potential.
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6. The application of phosphogypsum to agrochemical amelioration of saline complex soils is considered to have potential and could be recommended for further development.

The intensive growth in the production of phosphorus fertilizers requires a thorough investigation of the deterioration of the environment at the sites where the fertilizers are manufactured. In our study we attempted to assess the environmental situation in the workplaces of the mineral fertilizer plant in Voskresensk and adjacent territories and to examine its impact on the occupational staff and local residents. The results obtained could be generalized for the analogous plants elsewhere by referring to the chemical composition of the raw material and final products of five enterprises for fertilizer production at the territory of the former Soviet Union (Table 12). Almost all nitrophosphate fertilizers, as shown in Table 12, contain associations of element-pollutants. The application of these fertilizers on the agricultural fields inevitably leads to the deterioration of soils by these elements and to their migration through the chain: agricultural vegetation—animal—man. To understand the global impact of this kind of industry on the environment, it is necessary to continue complex biogeochemical studies on a larger scale.

This research was supported by the International Atomic Energy Agency Coordinated Research Program (IAEA CRP), under a contract No. 9480/Ro/R1.

Table 11. Mean Concentration of Chemical Elements in Soil and the Sudan Grass When Ameliorated by Phosphogypsum in the Amount of 10 ton/ha, mg/kg (except as noted)

<table>
<thead>
<tr>
<th>Object</th>
<th>Introduced Amount</th>
<th>F (%)</th>
<th>Na (%)</th>
<th>P (%)</th>
<th>S (%)</th>
<th>K (%)</th>
<th>Ca (%)</th>
<th>Sc (%)</th>
<th>Cr (%)</th>
<th>Fe (%)</th>
<th>Co (%)</th>
<th>As (%)</th>
<th>Br (%)</th>
<th>Sr (%)</th>
<th>Sb (%)</th>
<th>La (%)</th>
<th>Ce (%)</th>
<th>Sm (%)</th>
<th>Th (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Chestnut Soil</td>
<td>Background (n=10)</td>
<td>0.03</td>
<td>1.0</td>
<td>0.03</td>
<td>0.1</td>
<td>1.6</td>
<td>2.1</td>
<td>13</td>
<td>120</td>
<td>2.8</td>
<td>23</td>
<td>7.4</td>
<td>9.8</td>
<td>160</td>
<td>3.1</td>
<td>24</td>
<td>53</td>
<td>5.1</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>PG (n=30)</td>
<td>0.01</td>
<td>0.89</td>
<td>0.09</td>
<td>0.09</td>
<td>1.9</td>
<td>1.9</td>
<td>16</td>
<td>150</td>
<td>3.6</td>
<td>20</td>
<td>6.1</td>
<td>6.4</td>
<td>260</td>
<td>2.8</td>
<td>41</td>
<td>68</td>
<td>9.7</td>
<td>9.1</td>
</tr>
<tr>
<td>Sudan grass</td>
<td>Background (n=10)</td>
<td>&lt;0.01</td>
<td>0.06</td>
<td>0.20</td>
<td>&lt;0.01</td>
<td>3.0</td>
<td>0.5</td>
<td>0.04</td>
<td>0.7</td>
<td>0.02</td>
<td>0.6</td>
<td>&lt;0.1</td>
<td>160</td>
<td>&lt;50</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.02</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>PG (n=30)</td>
<td>&lt;0.01</td>
<td>0.02</td>
<td>0.25</td>
<td>&lt;0.01</td>
<td>3.0</td>
<td>0.7</td>
<td>0.05</td>
<td>0.9</td>
<td>0.02</td>
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<td>80</td>
<td>&lt;50</td>
<td>&lt;0.05</td>
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<td>1.3</td>
<td>0.03</td>
<td>0.1</td>
<td>1.2</td>
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<td>Sudan grass</td>
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<td>&lt;0.01</td>
<td>0.08</td>
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<td>&lt;0.01</td>
<td>2.5</td>
<td>0.4</td>
<td>0.06</td>
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<td>0.02</td>
<td>0.8</td>
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<td>140</td>
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<td>&lt;0.01</td>
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<td>0.09</td>
<td>0.8</td>
<td>0.03</td>
<td>0.5</td>
<td>&lt;0.1</td>
<td>120</td>
<td>&lt;50</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.03</td>
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Table 12. Concentration of Chemical Elements in Mineral Fertilizers of Different Plants, mg/kg (except as noted)

<table>
<thead>
<tr>
<th>Location</th>
<th>Type of Product</th>
<th>Na (%)</th>
<th>P2O5 (%)</th>
<th>Ca (%)</th>
<th>Sc (%)</th>
<th>Ti (%)</th>
<th>Cr (%)</th>
<th>Mn (%)</th>
<th>Fe (%)</th>
<th>Co (%)</th>
<th>Zn (%)</th>
<th>As (%)</th>
<th>Br (%)</th>
<th>Sr (%)</th>
<th>Sb (%)</th>
<th>La (%)</th>
<th>Ce (%)</th>
<th>Sm (%)</th>
<th>Th (%)</th>
<th>U (%)</th>
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<tr>
<td>Kovdor</td>
<td>Fluorineless phosphate</td>
<td>0.10</td>
<td>57</td>
<td>26</td>
<td>3.5</td>
<td>0.08</td>
<td>45</td>
<td>&lt;100</td>
<td>0.25</td>
<td>3.8</td>
<td>&lt;50</td>
<td>1.5</td>
<td>0.01</td>
<td>100</td>
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<td>0.21</td>
<td>1.0</td>
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<td>Apatite</td>
<td></td>
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<td>&lt;5</td>
<td>430</td>
<td>30</td>
<td>3.5</td>
<td>&lt;50</td>
<td>1.5</td>
<td>0.18</td>
<td>210</td>
<td>5.0</td>
<td>0.18</td>
<td>1.0</td>
<td>210</td>
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<td>Yegor’evsk</td>
<td>Concentrate</td>
<td>0.37</td>
<td>26</td>
<td>21</td>
<td>6.2</td>
<td>0.14</td>
<td>37</td>
<td>760</td>
<td>6.1</td>
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<td>130</td>
<td>50</td>
<td>1.8</td>
<td>120</td>
<td>5.0</td>
<td>0.13</td>
<td>1.0</td>
<td>240</td>
<td>5.0</td>
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<td></td>
<td>Phosphorite powder</td>
<td>0.35</td>
<td>28</td>
<td>21</td>
<td>6.0</td>
<td>0.11</td>
<td>33</td>
<td>840</td>
<td>6.0</td>
<td>38</td>
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<td>Flotation concentrate</td>
<td>0.22</td>
<td>36</td>
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<td>18</td>
<td>1,700</td>
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<td>29</td>
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<td>1.6</td>
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<td>&lt;1</td>
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<td>51</td>
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<td>3.0</td>
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<td>7.0</td>
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<td>40</td>
<td>6.0</td>
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References


8. Gost 17.2.01-86.

9. Gost 17.2.4.02-81.

10. Gost 5681-84.

11. Gost 17.4.4.02-84.


13. Gost 18.96.3-73.


Introduction

An environmental management system (EMS) is a standardized tool that enables companies to deal systematically with environmental issues and their communication within and outside the company. An EMS can lead to certification-registration, which can be an advantage in business. This paper will introduce the training material for seminars, “train the trainers” material, and self-teaching materials that are provided by the Training Resource Kit, a product of three partners—United Nations Environment Programme (UNEP), International Chamber of Commerce (ICC), and International Federation of Consulting Engineers (FIDIC).

EMS Supported by UNEP, ICC, and FIDIC

An EMS is a comprehensive method for reviewing, evaluating, and improving the environmental performance of an enterprise. An EMS helps to introduce good environmental conduct and assists in harmonizing trade. Thus, EMS is becoming an important means of acquiring business opportunities through export markets. Similarly, an EMS is also a tool for communication with interested parties, e.g., stakeholders or the general public.

The development and dissemination of the EMS Training Resource Kit is a joint project of UNEP, ICC, and FIDIC, being convinced that an environmental management system is an essential and effective tool to improve processes of business practice towards sustainable development.

Published in 1995, the EMS Training Kit was designed to give trainers and managers the tools necessary to conduct training courses in environmental management systems for companies. The kit has proven to be a valuable tool and has been translated into 14 languages.

The EMS presented in the Kit was largely inspired by the final draft of the International Standardization Organization (ISO) EMS Standard ISO 14001 and by the Eco Management and Audit Scheme (EMAS) of the European Union.

What Is an EMS?

Structure and Basic Concepts of ISO 14001

ISO 14001: Environmental Management Systems—Specification with guidance for use was established in September 1996. ISO 14001 aims to be applicable to all kinds of organizations, regardless of their nature and size, and for all geographical, cultural, and social conditions. The success of the system depends on the commitment at all levels in the organization, especially the highest management level.

Scope—The ISO 14001 standard only contains requirements that can be checked objectively. This may serve a purpose for certification and registration and for self-declarations by the organization. The standard does not contain absolute environmental performance requirements, except the obligation to comply with legislation and the commitments to continual improvement and prevention of pollution. Therefore it is possible that two organizations with comparable activities achieve different levels of environmental performance although both comply with the ISO 14001 requirements.

The standard uses the same general management system principles as the ISO 9000 series, which is the series for quality management systems. Organizations may choose to use their existing ISO 9000 quality management system to include additional environmental management system elements.

The Deming Cycle—The ISO 14001 standard was structured according to a sequence that has come to be known as the “Deming cycle.” The concept is a sequence of steps one has to go
through for a successful control process (Figure 1). Deming advocated the following steps:

- **Plan:** A planning phase—the overall objectives and goals of the enterprise are established, and the methodologies for achieving them are developed.

- **Do:** An action phase—the plan is implemented, and the agreed-upon measures are taken in pursuit of the enterprise’s goals.

- **Check:** An evaluation phase—the actions taken under the plan are checked for effectiveness and efficiency, and the results are compared with the plan.

- **Correct/ Improve:** A corrective action phase—any deficiencies or shortcomings identified are repaired, the plan may be revised and adapted to changed circumstances, and procedures are reinforced or reoriented as necessary.

Deming emphasized that goals are never fully achieved and process improvement is never ending.

**The Content of ISO 14001**—The basis of the ISO 14001 standard is the following reasoning—the EMS is aimed at formulating and achieving an adequate environmental policy in the organization.

Therefore, the significant environmental aspects need to be identified, as well as the applicable requirements from the existing environmental legislation. On the basis of this knowledge the environmental policy is established, together with objectives, targets, and an environmental program to achieve objectives and targets.

To be able to realize the environmental program and to achieve control of the activities that are critical for the environment, the organization needs to establish several organizational measures. In addition to the level of control, the effects of this control also need to be measured, recorded, analyzed, and evaluated. Where necessary, corrective measures need to be taken. The correct functioning of the EMS is reviewed by system audits. Management reviews evaluate the continuous suitability of the EMS and can lead to revisions of policy, objectives, and targets. After this control and improvement, the cycle will start again. Refer to Figure 2 for the elements of ISO 14001.

ISO 14001 specifies documentation of procedures in two areas:

- In those situations where the procedures are necessary to prevent deviations from objectives.
- For measurements and monitoring as well as for evaluating compliance.

However, many organizations have concluded that for such reasons as communication, maintenance, and demonstration of their existence there are arguments in favor of increased documentation of procedures.

**ISO 14001 as a Tool for Achieving Sustainable Development**—In environmental management the ultimate goal is the level where the principle of sustainable development applies. Sustainable development is a term that was introduced in 1987 by the World Commission on Environment and Development (also called the Brundtland Commission after its chairperson) in their report “Our Common Future.” It is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

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**Figure 1. The Deming Cycle.**

**Figure 2. The Elements of ISO 14001.**
A more popular version of the definition is that we have to realize that we have not inherited the environment from our parents but that we have borrowed the environment from our children. Therefore, we should take care not to violate the limits of pollution and other environmental impacts that Earth can absorb. This level is much lower than current levels of emissions. This is the reason why national environmental policies in many countries aim at a dramatic reduction in pollution levels from several sectors of activity such as agriculture, traffic, and industry.

As a consequence of using ISO 14001, organizations can expect to pay constant attention to the possibilities for improving the EMS and environmental performance.

**How Can You Adapt an EMS to Your Enterprise?**

**The Environmental Management System Training Resource Kit (EMS Training Kit) by UNEP/ICC/FIDIC, 1997**

The EMS Training Kit provides a summary of key triggers outlining why companies should introduce an EMS. It also gives a detailed explanation of an EMS with examples of an initial environmental review protocol; an EMS audit protocol; and an introduction to integrating an EMS with health, safety, and quality management systems. Case studies from seven companies explain the environmental problems they were facing and the benefits realized from implementing an EMS.

The Kit also contains a Trainers’ Guide with suggestions for 1- and 2-day training programs and instructions for the use of case studies and the exercises. The lecture material consists of a text on background, purpose, and “the A to Z” of an EMS; checklists; 22 exercises; and a comprehensive collection of overhead transparencies that can be used in training courses.

The Kit is designed for trainers, enterprise managers who would train internally, consultants, and also for self-teaching. The main use of the Kit will be as a basis for seminars designed to:

- Introduce the concepts of EMS to senior management (raise awareness).
- Provide a basis for a training seminar for managers responsible for operational and environmental affairs to enable them to adopt EMS in their enterprises.
- Train the trainers who would later train enterprise managers.
- Facilitate a think-tank workshop for consulting engineers to help them provide their clients with ecologically sound solutions.

Historically, enterprises have managed environmental issues in three ways: no action, reactive management, and proactive management. No action or reactive environmental management may be beneficial in the short term, but the proactive approach will provide long-term benefits. This is why business leaders should adopt an EMS, and UNEP, ICC, and FIDIC encourage business leaders to use their EMS Training Resource Kit to assist them in this endeavor.

**The Guide to ISO 14001 Certification/Registration by UNEP/ICC/FIDIC, 1998**

Since the publication of the Kit, ISO 14001 as well as standards on Environmental Auditing (ISO 14010, 14011, and 14012) have been published and have received wide application.

Many organizations have gone through the certification process against ISO 14001. At the end of 1998 the number of ISO 14001 certificates worldwide exceeded 6,000.

The success of the EMS Training Resource Kit and the implementation of ISO 14001 and EMAS encouraged the three partners to develop and issue two additional practical tools to assist organizations in improving their environmental performance:

- A Guide to ISO 14001 Certification/Registration.
- An EMS Handbook, a company guide for practical implementation of an EMS.

The Guide to ISO 14001 Certification/Registration is intended for organizations that aim to develop their EMS to a level that will achieve certification. This Guide can be considered as complementary to the Kit. Organizations that have acquired knowledge of EMS through the Kit or through other means can also use this Guide as a stand-alone document.

In particular, the Guide provides descriptions of the requirements of ISO 14001 and discussion on the necessary documents and records, as well as guidance on the various requirements for certification. In addition, the Guide illustrates the philosophy upon which ISO 14001 is based, describes the EMAS of the European Union, and gives guidance on the ISO 14001 certification procedures.

The core chapter of the Guide shows how to comply with the requirements of ISO 14001 in a user-friendly way. This chapter is intended to satisfy the different needs of an organization in a pragmatic manner; for example, it differentiates between the documents and records that are required for certification and those that are optional.
The Environmental Management System Handbook

This Handbook, developed in 1999, is a complement to the EMS Training Resource Kit for design and implementation of an EMS.

The Handbook provides a checklist and a practical guide to implementing an EMS after having taken part in a seminar based on the EMS Training Resource Kit. It is meant for distribution at the seminars where the teaching material includes the EMS Training Resource Kit.

The Handbook is divided into two parts. Part one focuses on the concept of an environmental management system and on its implementation. It is aimed at enabling participants of the seminars to implement an EMS following a list of actions given in the checklist. Part two of this Handbook contains practical environmental information. This section provides generic information on major environmental issues in various media, for example, air and water. UNEP is currently developing a series of fact sheets focused on major environmental issues in developing countries.

FIDIC publications include proceedings; information for consulting engineers, project owners, and international development agencies; standard prequalification forms; contract documents; and client/consultant agreements. These are available from the FIDIC Secretariat in Lausanne, Switzerland.

In 1990 FIDIC took an important step in its commitment to sustainable development with the publication of its Policy Statement on Consulting Engineers and the Environment. Prepared by the Environment Committee (ENVC) of FIDIC, the policy statement provides a general framework for the consulting engineering profession to integrate environmental concerns into the decisionmaking for all engineering projects.

In 1994 a Guide for Action was published. This document was prepared to provide more detailed analysis of recommended actions for consulting engineers worldwide. Today's terms of reference of the ENVC are to:

- Further develop and implement FIDIC's Policy Statement on the Environment.
- Define the roles that consulting engineers might play in preventing or solving environmental problems.
- Establish collaboration or continue liaisons with relevant international organizations working toward sustainable development.
- Ensure that environmental issues are maintained on the agendas of FIDIC Annual Conferences.

In 1998 FIDIC established a "Task Group Sustainable Development," which is preparing a FIDIC policy aiming for sustainable development and is working out action fields where FIDIC as an organization, the consulting industry, and the individual consulting engineer can contribute most effectively to a sustainable development and a sustainable habitat.

Conclusion

This paper gives an overview of the latest activities of the three partners—UNEP, ICC, and FIDIC—in preparing tools for companies to design and implement an environmental management system and to conduct the certification process.

Apart from using EMS as a standardized tool to deal with environmental issues, we strongly recommend giving special attention to the internal management within a company and to continuous improvement of the services related to environmental issues.

Technical solutions or EVABAT (economically viable application of the best available technology) cannot be the only approach to achieve sound environmental management and even less a sustainable development. The
involvement of employees by awareness raising, training, internal communication and responsibilities is crucial to a feasible and significant environmental progress.

It is interesting to see that many sectors are facing similar environmental or sustainability problems in terms of image, introducing significant changes in business practice, and finding specific solutions for their own sectors.

Hereby several industries—the fertilizer industry and the consulting engineering industry—could benefit from an extremely beneficial cooperation among partners like UNEP or ICC by providing general training materials, supporting sectoral voluntary initiatives that give advice from conceptual approaches for new design of production processes, and developing new services in the client relationship.

Bibliography

Introduction

I am very happy for the opportunity to present the activities of the European Fertilizer Manufacturers’ Association’s (EFMA) Technical, Environmental, and Safety Committee (TESC). Nowadays in Europe important activities take place in this field, for which the manufacturer is responsible; these responsibilities go beyond the environmentally sound and safe production of fertilizers alone.

Before going into more detail, however, I would like to give a brief overview of the organizational structure of EFMA, and I refer to the presentation that I made on behalf of Dr. Aldinger, EFMA’s Director General, for a more detailed introduction of EFMA.

The organizational structure of EFMA is relatively simple, as shown in Figure 1. As governing or overseeing bodies we have the General Assembly, the Steering Committee, and the Presidium. The conceptual and executive work is done by standing committees, to which the industry sends their representatives. Each committee is headed by a Chief Executive Officer (CEO) responsible for fertilizers in a member company; the CEO is supported by a professional issue manager, who is usually based in Brussels.

As explained in my earlier presentation on behalf of Dr. Aldinger, an important part of EFMA’s mission is, and I quote: “anticipating and preparing for upcoming issues that may affect the industry, by being the industry’s spokesperson and sounding board and by providing its members with a wide range of statistical information and services.” Today I will highlight the activities of the Technical, Environmental, and Safety Committee (TESC).

**TESC Structure and Activities**

The TESC, as shown in Figure 2, consists of 19 experts from member companies and national associations and is headed by a CEO. The committee meets three or four times a year with the purpose of exchanging information and making decisions. The actual work is done in small work-
ing parties or ad-hoc groups and task forces. The following are some examples of these working parties:

- Permanent Working Group on Product Safety and Transport.
- Task Force for Best Available Techniques.
- Team on Occupational Exposure Limits.
- Task Forces for Environmental and Safety Reporting and Benchmarking.

In addition, some of the TESC members play an important role in coordinating special activities relating to fertilizers by participating in the European Committee for Standardisation (CEN), the United Nations (UN), and the Working Group on Fertilizers of the European Union (EU) Directorate General III.

**TESC Working Area and Activities**

The activities of the TESC are focused on technological, environmental, and health and safety aspects during the production, transport, and storage of fertilizers. The same aspects related to the application of fertilizers are dealt with in EFMA’s Agriculture and Environment Committee. Of course, there is some overlap in activities.

The TESC activities related to fertilizer production, transport, and storage can be visualized as part of a chain: Production → Transport → Storage. Throughout the chain, the “responsible care” principles can be applied. Major elements in areas where EFMA is active include:

- Chemical management, for instance, keeping data records.
- Incident reporting and analyses (lessons to be learned).
- Safety statistics.
- Environmental reporting.

A brief discussion of each of these four elements follows.

**Chemical Management**—How can we produce and use fertilizers in an environmentally sound and safe way? To answer this question one should know all possible information on the compounds that are involved and, even more, whether there are risks related to the production or use of these compounds and how to control them.

In EU Directives 67/548 and EU 91/155, fertilizers are not classified as dangerous substances or dangerous preparations; however, some of the intermediates used in the production, for example, ammonium nitrate, can be dangerous. The provision of product data for at least these products is mandatory.

In the early 1990s, EFMA member companies started to compile Harmonized Electronic Data Sets (HEDSETS) for 17 fertilizers and their intermediates. These HEDSETS contain information on composition, hazards, physical properties, toxicological aspects, and so forth, and can now be used as input for an even broader set of data, the Screening Information Data Sets (SIDS) for compounds produced in high volume, which is an initiative of International Council of Chemical Associations (ICCA).

Based on the data in the HEDSETS, EFMA produced Material Safety Data Sheets as an easy-to-read booklet for anyone on the shop floor involved with the day-to-day use of these materials. This work was completed in 1995.

**Incident Reporting and Analyses**—The reporting of accidents and narrow escapes is stimulated and encouraged by EFMA, and a uniform reporting scheme has been developed. The purpose of accident reporting is to learn and to take measures to prevent accidents from happening again.

From these accident reports, primary topics can be selected to be used as subject material in safety seminars. Each year in May the Permanent Working Group on Product Safety and Transport organizes a safety seminar in which accidents and narrow escapes are discussed and recommendations are made. This information can also be
used as a basis for guidelines and handbooks.

Over a 3-year period there have been safety seminars on ammonium nitrate, ammonia, and nitric acid. As a result of these seminars, topics were selected for further research. The following are some of the areas selected for further attention:

- Inspection of ammonia storage (frequency and testing without opening).
- Transportation of nitric acid by tanks (simplified guidelines that can be used next to the existing European Agreements Concerning the International Carriage of Dangerous Goods by Rail (RID) and by Road (ADR) (RID/ADR) guidelines for the transport by road and rail.
- Discussions and recommendations on adaptation of existing detonation testing.
- Discussions and recommendations to simplify existing recommendations of the UN ammonium nitrate entries.
- Research on the runaway behavior of ammonia nitrate and the ways to control this behavior.
- Recommendations for safe loading and unloading.
- Discussion on standardizing TREMCARDs—special instructions that need to be present during transport of dangerous goods and can be used in case of emergencies.

**Safety Statistics**—EFMA monitors the safety performance of its members with the purpose of seeing how we perform and to see whether performance can be improved. The lost time injury rate (LTIR) is a good performance indicator for safety. It gives the number of accidents with absence from work for 1 day or more relative to total number of scheduled work hours by all employees. EFMA started in 1996 to collect LTIRs for employees and contractors from member companies. Although it is still too early to draw conclusions, some of the following trends can be seen:

- There is a difference in performance between companies.
- There is a higher LTIR for contractors.
- There is an average performance as compared with other associations.

**Environmental Reporting**—Also in 1996 EFMA started to collect emission data from the member companies. The purpose was internal benchmarking and to see whether the performance meets the Best Available Techniques (BAT) criteria. The emission data for nitrogen (ammonia and NOx) into water and air, dust into air, and phosphates into water are collected by an independent office in Zurich (AC Fiduciaire) and are graphically displayed. Each member company knows where it stands and how it performs when compared with others. On the basis of this information, improvements can be made. The information is also used to set emission levels that the industry can achieve by using BAT. The following sections focus on fertilizer production: some of EFMA’s activities in the area of technology, environment, and safety are highlighted.

**Integrated Pollution Prevention and Control (IPPC), BAT, and Best Available Techniques—Reference Documents (BATREFs)**

The EU’s Integrated Pollution Prevention and Control (IPPC) Directive aims at streamlining policies governing the control of industrial emissions by requiring companies to obtain an integrated operating permit, which stipulates emission values into air, water, and land. The Directive refers to BAT that cover both the technology applied and the operational practices employed. I would also like to refer you to the presentation on this subject given in Technical Session II by Dr. Samec.

Even long before this Directive came into force, EFMA pioneered work on BAT by founding a task force in 1993 to define BAT for the production processes of intermediates and finished fertilizers. The products covered in EFMA’s BAT booklets are:

- Ammonia.
- Nitric acid.
- Sulfuric acid.
- Phosphoric acid.
- Urea and urea ammonium nitrate solution (UAN).
- Ammonium nitrate (AN) and calcium ammonium nitrate (CAN).
- NPKs produced by the mixed acids route.
- NPKs produced by the nitrophosphate route.

The booklets were originally completed in 1995, and an update will be completed in 1999. They describe state-of-the-art operating conditions in Western Europe and give recommendations for BAT emission values for existing and new plants. They were prepared in order to share knowledge about BAT among the fertilizer manufacturers as well as with the regulatory authorities. The information will be used in the development of EU guidelines for BATs relating to other industrial sectors.

In 1997 the EU began producing about 35 different Best Available Techniques—Reference Documents (BATREFs), of which
“Bulk Inorganic Gases and Liquids” and “Bulk Inorganic Solids” are the most relevant to the fertilizer industry. Contributions from each Member State and from the fertilizer industry will eventually be consolidated into one EU document. EFMA has taken the lead in preparing the BATREFs for ammonia, nitric acid, and phosphoric acid, and, with the European Sulphuric Acid Association (ESA), for sulfuric acid.

**SEVESO II and Control of Major Hazards (COMAH) Directives**

The COMAH Directive 96/82/EU deals with the control of major hazards involving dangerous substances. The COMAH Directive is the result of the need to review the SEVESO Directive 82/501/EU because of:

- Inconsistency (varying degrees of implementation in different Member States).
- Exemptions made (explosives, chemicals, and nuclear plants).
- Gaps (land use planning is not addressed and insufficient emphasis is given to management).
- Inflexibility (long list of chemicals, which makes it impossible to keep up with change).

The main provisions of COMAH are:

- Identification of sites (quantities, categories).
- General duties (all measures taken to prevent).
- Major Accident Prevention Policy (competent management, monitoring, and auditing).
- Domino effect (proximity of sites).
- Safety reporting (up-to-date and open to the public).
- Emergency plans (internal and external plans).

- Land use planning (distance between plants/sites).
- Public information.
- Accident reporting (obliged to inform).
- Competent authority and inspections (administer, assess reports, and inspect sites).

The Member States of the EU were required to introduce their own legislation to implement by February 3, 1999. After that, but depending on the status, there is a certain time schedule to produce the “Safety Reports.” New plants have to produce the Safety Report before starting the construction or operation, whereas existing plants subject to SEVESO have 2 years and existing plants not subject to SEVESO have 3 years to produce the Safety Report.

**Safety and Health Aspects of Workers**

The safety and health of workers in the EU are regulated by several directives and their amendments. These directives give measures to encourage improvements in the safety and health of workers should there be risk of exposure to chemicals, carcinogens, and ionizing radiation. In addition, they give measures to protect workers from injuries by prescribing proper personal protective equipment and measures on how to use machinery in a safe way.

The first step, of course, is to limit the chance of exposure by instituting integrated process measures to prevent leakage to the workplace, which unfortunately is not always 100% possible.

EFMA and the EU discuss the safe levels of exposure within the context of the following factors, always, of course, keeping in mind the safety of the workers:

- Scientific studies.
- Presence and reliability of measurement methods.
- Availability of abatement technologies.
- Socioeconomic feasibility.

**Transport and Storage**

In this section on the transport and storage of fertilizer, some of EFMA’s activities in this field are highlighted. Transport of dangerous goods is regulated by UN recommendations for transport by road (ADR), rail (RID), sea (International Maritime Dangerous Goods Code [IMDG]/International Maritime Organization [IMO]), inland waters (International Carriage of Dangerous Goods by Inland Waterway [ADN]), and air (International Civil Aviation Organization [ICAO]). These recommendations classify the goods and give measures to be taken relative to:

- Packaging (bags and portable tanks).
- Marking (identification).
- Labeling.
- Documentation.
- Training.
- Tanker design.
- Filling aspects.

However, the information that these recommendations contain is extensive and sometimes difficult to interpret for nonexperts. Therefore, EFMA decided to publish guidelines that can be used by workers on the shop floor. These guidelines do not replace the existing legislation but go beyond them.

The following are some examples of EFMA Guidelines:

- Guidelines for Transporting Nitric Acid by Tanks (1998).


Another activity of EFMA’s Permanent Working Group on Product Safety and Transport is the simplification of existing regulations with the purpose of a better interpretation. The UN “orange book” on transportation of dangerous goods by road contains several entries for ammonium nitrate. Interpretation of these entries is often difficult because more and many different ammonium nitrate-based formulations are entering the market. The working group has developed a simple and easier to understand scheme to be submitted to the UN this year.

Additional Activities of EFMA

EFMA’s activities in the field of technology, environment, and safety are numerous, and it is not possible to discuss them all. However, the following activities are mentioned.

Activities Related to EU Fertilizer Legislation

The Simpler Legislation for the Internal Market (SLIM) initiative was launched by EU in May 1996. It can be seen as a part of the program to simplify EU legislation.

On October 27, 1997, a final report on the SLIM exercise on fertilizers was issued. The recommendations in this report were used in redrafting the EU legislation on fertilizers in January 1999. EFMA gave input to this exercise.

Activities Related to Energy

There is a proposal for a directive (“Monti” Directive) regulating the energy tax at the EU level. The situation in the EU Member States has changed recently. Most Member States are more or less in favor of some EU regulation of taxes on energy products. The fertilizer industry is among the largest consumers of energy and thus must be involved. EFMA shares the following position of the chemical industry:

- Oppose taxes.
- Go for long-term negotiated agreements.
- Reward companies that have achieved energy reductions.

Activities Related to Greenhouse Gases and Post Kyoto/Buenos Aires Implementation

Nitrous oxide (N₂O) is an important greenhouse gas because it contributes to global warming. Main sources of emissions are agricultural land, forests, and oceans on the one hand and human activities like production of adipic acid and other organic compounds and fertilizers on the other hand. Available emission data vary widely, and the contribution of the fertilizer industry to global warming is less than 10%. Therefore, EFMA’s efforts are focused on putting the situation in a better perspective before starting discussion on reduction targets.

Activities Related to the Image of Using Fertilizers

EFMA is of the opinion that there are positive stories that can be told about using fertilizers. On behalf of EFMA, the University of Halle Wittenburg in Germany has performed a study with the purpose of determining whether there is a gain in energy in the use of fertilizers. In a type of life cycle approach, the energy balance starting from mining and production to transport to the farm and up to the harvest of crops was determined. The results are very promising, and EFMA is considering publication of this study.

Activities Related to EU Enlargement

For 4 years EFMA organized, with the EU, the so-called “East-West” Seminars; the last one was in Prague in 1998. The purpose of these seminars was to inform fertilizer producers and ministries in the Eastern European countries of EU legislation and the legislative process and to assist them in their preparations to adapt to EU requirements as part of the accession process. In 1999 EFMA invited young managers from fertilizer producers in Eastern European countries to attend a tailor-made summer course the entire month of June in Brussels. Besides intensive introductions in technical, environmental, safety, agronomic, trade, economic, and statistical issues, the participants will also be introduced to the EU legislation and legislative process and what is needed in the accession process of the Eastern European countries. Of course, there are also visits to some Western European fertilizer production plants and to farms.

The kind of dialogue offered by this workshop is appreciated very much by participants, and I am sure that the results of this workshop will be appreciated as well.

Conclusion

Today, producers of fertilizers in Europe have to face a variety of legislation regarding environment and safety issues. To deal with this in a responsible but cost-effective way, it is best to unite forces and join an association. The European Fertilizer Manufacturers’ Association provides a good environment for achieving this goal. This presentation gives an overview of the activities of EFMA’s Technical, Environmental, and Safety Committee and what has been achieved.
Introduction

On Sunday December 7, 1997, the Florida Department of Environmental Protection (FDEP) was notified of a spill of process wastewater from one of the fertilizer manufacturing plants in west central Florida, U.S.A. The process wastewater was contained within an impoundment on top of the 110 ft (34 m) high phosphogypsum stacking area as well as in cooling ponds. The FDEP performed a site inspection in response to the facility’s notification of the spill and provided assistance and guidance to the facility representatives. A discussion of this spill incident and the impact it had on the environmental rule-making process follows.

Spill Incident

The site inspection revealed that the spill had been caused by the failure of a portion of an impoundment within the phosphogypsum stack system, resulting in the discharge of approximately 54 million gal (0.2 million m³) of process wastewater. This volume of wastewater overwhelmed the ditching and recirculation control system and discharged off-site into Skinned Sapling Creek. Skinned Sapling Creek is a tributary of the North Prong of the Alafia River. Over the course of the next 7 to 10 days, the volume of discharge originating in Polk County at a location immediately east of the city of Mulberry traversed approximately 38 miles (63 km) of the Alafia River to Tampa Bay. As is typical of phosphoric acid production wastewater, the released wastewater contained approximately 1.0% phosphoric acid and had a pH of about 2.0.

The FDEP immediately evaluated available remedial options and recommended limited neutralization of the discharged wastewater using lime. FDEP also contacted neighboring phosphate companies and the government wastewater and storm water facilities, requesting them to increase the amount of treated wastewater and storm water discharge to help dilute the effects of the spill. The subsequent unusually heavy El Niño rains appeared to dilute the effects even further, which accelerated the pH recovery of the river system.

A warning letter followed, which notified the facility of applicable permit and rule violations and required them to initiate a sampling and assessment program. The FDEP also initiated an independent sampling and damage assessment plan. In that the release of the process wastewater violated several federal, state, and local regulations, a damage assessment team comprising representatives from federal, state, and local agencies was formed.

Response actions carried out by FDEP were sufficient to stop the source of the release, monitor the movement of the released process wastewater as it moved toward Tampa Bay, document the effects of the release on certain water-quality parameters, protect the public from potential risks associated with use of the river during the spill event, and allow some actions in an attempt to minimize potential effects of the spill. FDEP collected water-quality data from several locations, which indicated the impact from the spill.

Impact of the Spill

The most significant effect of the spill was the depression of the river water pH along 38 miles (63 km) of the Alafia River: pH levels ranged from 2.3 standard units in the upper, freshwater portion of the Alafia River to 4.0 standard units in the lower, estuarine portion for several days. The low pH resulted in significant fish mortality in the Alafia River and observable injuries to shoreline and upland vegetation as well as losses of resource services. Pursuant to discussions at a damage assessment team meeting, it was decided that a restocking effort for the Alafia
River should be initiated. The initial effort comprised the release of about 154 snook into the Alafia at six different locations on May 22, 1998. The snook were spawned at FDEP’s Stock Enhancement Research Facility (SERF) on August 19, 1996, from locally captured brood stock, and were part of a growth and nutrition study at the Harbor Branch Oceanographic Institution. Upon completion of the study, the snook were transferred back to SERF’s hatchery to be re-acclimated to seawater, tagged, and checked for health prior to release.

The released snook averaged 11 inches (28 cm) in length and were fitted with visible tags so anglers can help FDEP scientists monitor the location and survival of the fish for the purpose of determining whether or not restocking of the river is a viable option. Any fisherman who catches a tagged fish is required to call the FDEP Fish Tag Hotline.

In May 1999, the FDEP released the first draft report on fish, blue crab, and pink shrimp mortality in the Alafia River as a result of the spill. The draft report estimated mortality at approximately 1.3 million animals. Also, on April 6, 1999 in Tampa, the FDEP’s aquatic vegetation assessment group presented its preliminary findings. The assessment involved intensive field surveys together with documentation of the river system using infrared and color photography. The vegetation damage appeared to be restricted to a limited area of approximately 377 acres (153 ha) in the upper portion of the river in Polk County. Based on information provided by preassessment investigations, the assessment team identified two additional types of natural resource injuries or losses, namely, surface water and freshwater benthic invertebrates. In the category of surface water, the release substantially reduced the pH in the river to levels below water quality criteria. The release also added nutrients, such as phosphorus and nitrogen, in the surface waters of the Alafia River and portions of Tampa Bay. As for the freshwater benthic invertebrates, when compared with control and background stations, sampling stations downstream from the spill site demonstrated a decrease in the abundance and diversity of the benthic species after the spill. This indicates an injury to freshwater benthic communities.

**Restoration Alternatives**

The framework for identifying preferred restoration alternatives consisted of the recommendation from the restoration work group and the public through a public notice in the local newspapers seeking input on restoration alternatives. Through these activities, the damage assessment team identified ten potential restoration alternatives. All restoration alternatives were then screened based on the restoration criteria.

The following five restoration alternatives with the highest overall scores were selected for further detailed consideration:

- Water Quality Improvement Projects.
- Restoration of Riverine Habitats.
- Artificial Reefs.
- Land Acquisition.
- Restoration of Low-Salinity Habitat.

The investigation of the team thus far has resulted in a draft report on fish mortality, estimation of damage to aquatic vegetation and benthos invertebrates, and determination of lost human use of the resource as a result of the spill. Final reports on damage assessment activities will be completed and made available to the public by the end of November 1999.

**Rule Development and Content**

Immediately after the spill, FDEP convened the Phosphogypsum Impoundment Technical Advisory Forum (PITAF), composed of technical experts from academia, private consulting firms, the phosphate industry, the Florida Institute of Phosphate Research (FIPR), and regulatory agencies. The PITAF was established to (1) analyze the spill incident to determine underlying causes and review existing industry practices, rules, regulations, and statutes pertaining to the sufficiency of phosphogypsum impoundment structures; (2) propose alternative best management practices for design, construction, quality assurance, and operation of such structures; and (3) recommend procedural and regulatory measures to prevent future spills.

The PITAF met 13 times over the course of 7 months, each a day-long meeting, which included the educational phase of the PITAF as well as site visits to several phosphate fertilizer manufacturing facilities. Finally, PITAF concluded their work in a report issued in October 1998.

In response to the public concern shortly after the accidental spill, a bill was introduced to the Florida legislature to adopt rules addressing safety standards and emergency practices. The mandate for rule making resulted from the Florida legislature’s passage of what ultimately became chapter 98-117, Laws of Florida. This law requires that the FDEP adopt rules to ensure that phosphogypsum management impairment structures and water conveyances are designed and maintained to meet...
critical safety standards. Any impoundment and all appurtenant structures and equipment must be built using sound engineering practices and operated to avoid spills. In addition, facility owners must keep detailed operational logs and must have contingency plans to respond to emergencies at phosphogypsum stack systems (sites).

When chapter 98-117 became law, the FDEP requested that the PITAF provide rule-making assistance. The rule changes required by chapter 98-117, Laws of Florida, have been incorporated into Part II of chapter 62-672 of the Florida Administrative Code (FAC). The rule revisions, which also address dam safety, were approved on March 28, 1999, for adoption by the Florida Environmental Regulation Commission and will become effective June 28, 1999. The specific provisions of Part II of chapter 62-672 FAC will be summarized; some of the terminology used in this rule can be found in Figure 1.

- Section 62-672.600 FAC sets forth the design, site preparation, and materials to be used; process water control design; methods of construction; and documentation requirements for the construction of new perimeter earthen dikes. These requirements are necessary to ensure that new perimeter earthen dikes are constructed using sound engineering practices and to meet critical safety standards. The design requirements apply to both new and existing dikes. The design details include numerous design criteria such as soil testing, stability, analysis, and safety factors.

- Section 62-672.620 FAC sets forth requirements for assessing existing perimeter earthen dikes and a timeframe to document the safety of the existing dikes; those that do not meet the rule’s requirements must be taken out of service within a prescribed timeframe.

- Section 62-672.650 FAC sets forth the operational requirements for perimeter earthen dikes. This section of the rule requires the design freeboard of 5 ft (1.52 m) to be maintained; however, given the complexity of the chemical operations, the rule allows the temporary use of the freeboard provided the safety of the dike is examined by an independent professional engineer and approved by the FDEP to ensure that operation of perimeter earthen dikes will not result in spills or discharges of materials that adversely affect surface or ground waters.

- Section 62-672.670 FAC sets forth the inspection and maintenance requirements for perimeter earthen dikes and outlines the frequency of inspections and the requirement that the owners of perimeter earthen dikes keep logs on their inspections and any corrective actions taken. One of the most noteworthy sections of this rule by far is the inspection and postinspection requirements for perimeter earthen dikes and phosphogypsum stacks. Above and beyond all routine daily, weekly, monthly, and quarterly inspection requirements, each perimeter earthen dike and phosphogypsum stack must be inspected annually by an independent professional engineer to document its safety and stability.

- Section 62-672.700 FAC addresses the construction requirements for new phosphogypsum stacks. These requirements are necessary to ensure that new phosphogypsum stacks are constructed using sound engineering practices and to meet certain critical safety standards. All new stacks and expansion of the existing stacks must be designed with an overall 1.5 safety factor.

Figure 1. Components of a Phosphogypsum Stack System.
Section 62-672.720 FAC sets forth the requirements for assessments of existing phosphogypsum stacks. For existing stacks whose stability cannot be verified, it is specified that they must be upgraded or retrofitted to meet the requirements of the rule while interim measures proposed by the third party professional engineer are enforced.

Section 62-672.750 FAC sets out the procedures for raising phosphogypsum stacks. This section is necessary to ensure that phosphogypsum stacks are raised to avoid spills or discharges of materials that adversely affect surface or ground waters. The detailed procedures for raising phosphogypsum stacks include criteria for the crest width of the dike, the slope, and the thickness of each gypsum dike lift.

Section 62-672.760 FAC sets forth the procedures for deconting process water from the top of a phosphogypsum stack to avoid spills. More specifically, there are three decant methods that are allowed under this rule:

- Siphon line, which does not penetrate the gypsum dike.
- Open cut dug in the gypsum with maximum depth of flow of 2 ft (0.61 m).
- Decant pipe placed in a backfilled cut.

The rule also limits the allowable depth of any open cut used to decant water and any cut made to place or remove a decant pipe to a maximum of 10 ft (3.05 m). The depth of the cut is measured from the top of the fluid level in the rim ditch at the decant location to the bottom invert elevation of the decant pipe or open cut beneath the centerline of the gypsum dike (Figure 2).

If a decant pipe is used, and a cut is made to place or remove the pipe, one of the following three precautionary measures must be implemented prior to making a cut:

**Option 1**
Construct a gypsum “beach” or delta on the inner settling compartment extending no less than 30 ft (9.1 m) from the inside edge of the crest of the inner levee followed by lowering the water level below the bottom invert elevation of the decant pipe, and then construct a temporary cofferdam on the gypsum beach (Figure 3).

**Option 2**
Construct a gypsum “beach” or delta on the inner settling compartment extending no less than 100 ft (30.5 m) from the inside edge of the crest of the inner levee, and construct a temporary gypsum cofferdam as needed to isolate the decant location. The cofferdam must have a minimum crest width of 20 ft (6.1 m), and the excavation is not allowed to extend across an imaginary line (3.0 horizontal to 1.0 vertical) projected from the outside toe of the cofferdam toward the exterior slope of the stack (Figure 4).

**Option 3**
Construct a gypsum “beach” or delta on the inner settling compartment extending no less than 500 ft (152 m) from the inside edge of the crest of the inner levee (Figure 5).

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**Figure 2. Allowable Depth of Cut.**
**Figure 3.** Precautionary Measures Prior to Decant Pipe Removal (Option 1).

**Figure 4.** Precautionary Measures Prior to Decant Pipe Removal (Option 2).

**Figure 5.** Precautionary Measures Prior to Decant Pipe Removal (Option 3).
Section 62-672.770 FAC sets out the inspection and maintenance requirements for phosphogypsum stacks. The inspection requirements are similar to the inspection requirements for earthen dikes. The frequency of inspections is outlined. All phosphogypsum stacks must also be inspected annually by an independent professional engineer to document its safety and stability.

Section 62-672.780 FAC addresses the requirements for operation plans needed for each phosphogypsum stack system to ensure that stack systems are operated to avoid spills or discharges. This section of the rule requires each facility to maintain a site-specific operation plan for each aspect of the entire phosphogypsum system, including a site-specific water management plan which ensures that each facility has sufficient impoundment capacity to handle extreme rainfall events. Each facility must implement its site-specific plan, and it must be updated annually to reflect changes in watershed area and storm surge. This plan must be based upon a 5-year water balance analysis, which is renewed at 5-year intervals. Each plan must specify a set of specific actions that are put into motion when certain “triggers” are exceeded in the cooling/surge pond system.

Each trigger corresponds to the operating water level[s] needed to contain the storm surge or fraction of the storm surge from the specific design storm (e.g., 100-year, 24-h event). These triggers are:

- “ACTION PLAN” trigger—Activated when the surge capacity equivalent to a 12-inch (30 cm), 24-h rain event is encroached. When this level is exceeded for two consecutive days, the facility owner must present to the FDEP a site-specific action plan for process water inventory management.

- “MAY TREAT” trigger—Corresponds to an encroachment into the surge capacity equivalent to runoff from a 24-h, 25-year storm event. When this level is exceeded for two consecutive days, the facility owner may treat process water and discharge or take other actions as prescribed in the facility’s permit.

- “MUST TREAT” trigger—Activated when half of the 24 h, 25-year surge capacity is encroached. When this level is reached or exceeded, the facility must treat and discharge as prescribed in the facility’s permit.

These requirements are illustrated more specifically in a graphical form in Figure 6.

Section 62-672.800 FAC sets forth the training requirements to which owners of phosphogypsum stack systems must adhere.

Section 62-672.850 FAC requires that owners of phosphogypsum stack systems prepare a contingency plan, updated annually, to demonstrate the ability to address the unplanned releases of process water.

Section 62-672.870 FAC requires that owners of phosphogypsum stack systems plan for and implement, when necessary, emergency measures to address unusual rainfall events in order to avoid the unplanned release of process water.

**Conclusion**

The rule development that was stimulated by the December 7, 1997, process wastewater spill from one of Florida’s phosphate fertilizer complexes incorporates specific procedures that will drastically decrease or almost eliminate accidental discharges from phosphate facilities.

![Figure 6. Cooling/Surge Pond System Trigger Levels.](image-url)
Introduction

The International Fertilizer Industry Association (IFA) and the United Nations Environment Programme (UNEP) with the support of the United Nations Industrial Development Organization (UNIDO) have produced a technical report entitled *Mineral Fertilizer Production and the Environment*. In this paper the background to the preparation of this and related publications, and their purpose, are explained.

Background

The origin of this technical report can be traced to the United Nations Conference on Environment and Development (UNCED), also known as the “Earth Summit,” held in Rio de Janeiro in 1992. We expected that the fertilizer industry would come under strong attack at UNCED: the environmental movements were extremely active at the time, and mineral fertilizers had not been spared. In anticipation of the attacks, the European Fertilizer Manufacturers’ Association (EFMA), IFA, and the Potash and Phosphate Institute (PPI) prepared a 16-page document, including a 4-page summary, entitled “Sustainable Agricultural Systems for the Twenty-First Century: The Role of Mineral Fertilizers.” This document was supported by ten fertilizer industry associations. With the help of the International Chamber of Commerce (ICC), the fertilizer industry was well represented at the Rio conference. We were pleasantly surprised at the outcome. There was a good demand for the document, and there was nothing really prejudicial to the industry in the action plan, known as “Agenda 21,” adopted at the Summit.

Agenda 21, however, places a responsibility on business and industry to “recognize environmental management as among the highest corporate priorities and as a key determinant to sustainable development.” The mineral fertilizer industry is no exception.

To quote some relevant sections from Chapter 30 of Agenda 21, “Strengthening the Role of Business and Industry”:

Business and industry, including transnational corporations, should be encouraged: to report annually on their environmental records, as well as on their use of energy and natural resources; and to adopt and report on the implementation of codes of conduct promoting the best environmental practices.

Industry and business associations should encourage individual companies to undertake programs for improved environmental awareness and responsibility at all levels to make these enterprises dedicated to the task of improving environmental performance based on internationally accepted management practices.

Furthermore, the relevant sections of Agenda 21 encourage industry to embark on a process of continuous improvement, rather than merely adopting a rigorous set of imposed standards or regulations.

It is in this context that IFA has taken up the challenge presented by the “Earth Summit.”

The Challenge

The processes involved in the production of fertilizers generate emissions that may contribute to global environmental problems (for example, the greenhouse effect and ozone depletion) as well as local environmental problems such as acid rain, acidification, eutrophication, chemical mist, liquid effluents, and solid wastes including phosphogypsum. If fertilizer production facilities are to realize the lowest achievable environmental impact, both locally and globally, it is important that high standards of operation and maintenance be imple-
ment. It is also necessary to monitor and measure the emissions to air and discharges to water, in total and per unit of output, to allow comparison with previous years and to enable operators to take corrective action if the effluents deviate from design conditions.

Until recently, specific actions to resolve separate air, water, and waste problems were the norm in most industries and governments. The traditional approach to environmental policy concentrated on effects rather than causes. In many countries it is still the main way in which environmental issues are addressed. While some improvements in environmental quality certainly resulted from this approach, its limits also soon became apparent. The need to look at all the impacts simultaneously and to address the priority areas in a systematic way has now become more or less universally accepted. Preventive rather than remedial action forestalls and minimizes the excessive costs involved in treating pollution after it has been produced.

The two preceding paragraphs are taken from a paper on a similar subject which I presented at the previous IFDC International Environmental Workshop held in Atlanta, Georgia, in September 1997. I wondered whether it was worthwhile repeating them in this paper in that the approach outlined is now so generally accepted. This demonstrates the pace at which acceptance of environmental concerns is progressing.

United Nations Environment Programme

The opportunity to follow up on the positive experience at the “Earth Summit” came in 1994 when the then Industry and Environment (IE) office of the United Nations Environment Programme (UNEP) proposed to IFA that a technical report be prepared on the fertilizer industry. In 1998 the IE Division of UNEP became the Division of Technology, Industry, and Economics (TIE). The UNEP-TIE Division, centered in Paris, works in partnership with various industry sectors, in order to encourage decision makers in government, industry, and business to develop and adopt policies, strategies, and practices that are cleaner, safer, use natural resources more efficiently, and reduce pollution risks to human beings and the environment.” UNEP has prepared technical reports with several major industries (oil and gas, steel, pulp and paper, mine tailing dams, brewing, electronics, textiles, nonferrous metals, tanneries, tourism, and sugar).

The publication proposed in 1994 would represent the fertilizer industry’s contribution to the UNEP Sustainable Production and Consumption Programme. The outcome was the publication in December 1996 of the IFA/UNEP report entitled Fertilizer Production and the Environment. To keep the document to a reasonable length, environmental issues concerning the mining and beneficiation of phosphate rock and potash ores were not included.

A second edition of the publication was issued in December 1998 entitled Mineral Fertilizer Production and the Environment. Technical Report No. 26. For the second edition we divided the first edition into two parts. The first part concerned the production processes. Some errors were corrected and new information added, but it is very similar to the first half of the first edition. The second part dealt with environmental management systems.

IFA’s cooperation with UNEP has several advantages:

- IFA benefits from UNEP’s experience with other industries.
- UNEP comments on the text, makes suggestions for the content, and introduces new ideas.
- Information reaches a wider audience through the UNEP distribution network.

The Issues

An outline of the content of the two parts of Mineral Fertilizer Production and the Environment, Technical Report No. 26, each containing some 70 pages, follows:

Part 1: Manufacturing Processes and Environmental Issues

- The Development of the Fertilizer Industry.
- Processes for Fertilizer Production.
- Energy, Cleaner Production, and Major Hazards.
- Environmental Issues.

The aim in this part of the report was to be technically accurate but also communicate in a language that is understandable to the nonspecialist.

Part 2: Environmental Management Systems

- Environmental Management Systems.
- Environmental Management Tools.
- Environmental Approaches.
- Regulatory and Planning Framework.
- Emission Standards and Integrated Pollution Control.
- Negotiated Agreements and Voluntary Control.

Environmental management systems (EMS) evolved so rapidly between 1996 and 1998 that this
section of the report had to be rewritten completely.

The Audience

Mineral Fertilizer Production and the Environment is intended to be a broad introduction to the subject and to serve as follows:

• Inform people within the fertilizer industry of the latest developments in EMS.
• Provide background information for government officials responsible for regulating the fertilizer industry. The document is made available by UNEP to relevant government organizations.
• Provide fertilizer manufacturers who are upgrading their plants with information on experience elsewhere in the world.
• Help employees in the fertilizer industry to understand the environmental issues.
• Provide objective and factual information on the considerable achievements of the fertilizer industry as regards cleaner production. Hence, the target audiences of the publication are:
  • Policymaking bodies outside the fertilizer industry whose decisions affect the industry.
  • The fertilizer industry, particularly in countries where the industry is still being established or where action is needed to correct past unsatisfactory practices.
  • The fertilizer industry as a whole, by drawing on UNEP’s experience with other industries and their expertise in environmental management systems.
  • Environmentally aware nongovernmental organizations (NGOs).
  • The general public.

Some Topical Issues

Global Warming
At the Rio “Earth Summit” in 1992, states agreed on a voluntary limitation of greenhouse gas emissions. The development was taken further with the “Kyoto Protocol” of 1997. This protocol provided for reductions on emissions of the greenhouse gases, which would be legally binding on countries that ratify the protocol. The objective is for industrialized countries to reduce overall emissions of a “basket” of six greenhouse gases by at least 5% (CO2 equivalents) below 1990 levels by 2008 to 2010. The protocol is flexible in that it allows, for example, for the international trading of emissions, and the increase (or decrease) in “carbon sinks” during the commitment period may be taken into account.

To come into force the Protocol has to be ratified by 55 countries, and to date only a handful have done so. In particular the United States Senate is very reluctant to approve ratification. However, some countries have already taken action as if it were in force. Particular reference is made to the paper presented by Mr. Mark Radka at this Workshop (Technical Session VI), which is devoted to the subject.

Some West European countries are using fiscal measures such as the following to achieve the objective.

United Kingdom
• Proposed levy on the business use of energy (not carbon) from April 2001 onward.
• Nonenergy use of fuel excluded.
• Lower tax rates for energy-intensive sectors, conditional on agreed-upon energy efficiency/carbon savings targets.

Denmark
• Gradual increase in CO2 tax from 1996 to 2000.
• All revenue to be recycled by lowering wage-related taxes and providing subsidies to promote energy efficiency.

• Lower tax rate for energy-intensive processes with tax reduction depending on company’s energy management system.

Integrated Pollution Prevention and Control (IPPC)

The European Union’s IPPC Directive of September 1996 defines the procedural framework for obtaining a permit to establish a new facility. As an EU Directive it must be implemented by legislation in the member states. It requires that pollution at all stages of the process be considered and that the pollution not simply be transferred from one medium to another. Enforcement is the responsibility of the local authorities, but they must act within the framework of the Directive. It provides a common reference ground for permitting and supervising industrial activities. The procedures are transparent and open to public scrutiny. EFMA anticipated the Directive and its implementation by preparing a series of eight Best Available Technique (BAT) booklets covering eight important fertilizer intermediates and products. The BAT booklets are discussed in detail in a paper presented by EFMA in Technical Session IV.

Information

There are two aspects of the need to make available to the public information concerning the fertilizer industry’s response to environmental concerns: first, the public’s “right to know” and second, the fertilizer industry’s interest in providing objective and factual information on the considerable achievements the industry has made concerning cleaner production.
The Brundtland Report ("Our Common Future," 1987) recommended the recognition of certain rights:

The right of individuals to know and have access to current information on the state of the environment and natural resources and the right to be consulted and to participate in decision making on activities likely to have a significant effect upon the environment.

Several fertilizer manufacturing companies are now issuing environmental reports, many reporting their emission performance. Attention is being paid to informing the community in the neighborhood of the plant and to discussing actual or potential problems with them. Many companies have greatly reinforced the staffing of their environmental operations. The training and education of employees on environmental matters have been greatly increased. Among the other advantages of the establishment of environmental management systems is the fact that schemes such as The Eco-Management and Audit Scheme of the European Union (EMAS) and ISO 14000 raise awareness among employees of environmental issues. In many companies the environmental performance is reported regularly to the main governing board and discussed. Because this is far from being the case in all companies, a major objective of IFA publications is to demonstrate what is being done by some.

Using modern technology, emissions can be decreased to acceptable levels. In many industrialized countries, fertilizer manufacturers have made significant progress in this respect during the past two decades. It is not only in industrialized countries, however, that progress has been made—some of the best performing plants, from an environmental point of view, are those of the Arabian Gulf, and many manufacturers in the Indian subcontinent pay great attention to environmental aspects. Unfortunately, this is not the case in all regions of the world. An objective of IFA publications is, on the one hand, to make known to a skeptical public what has been achieved but also, on the other hand, to inform manufacturers with less than satisfactory operations about what is being done elsewhere.

**A Case From Australia**

The Western Mining Company (WMC) of Australia has an environment officer at each of its production locations. They are supported by 40 professionals. Each quarter the Chief Executive Officer submits site-by-site environmental reviews to the board.

In the fertilizer sector, a major WMC development is the "Queensland Phosphate Project" located at Phosphate Hill. The project comprises a 1-million-mtpy ammonium phosphate plant based on using local phosphate rock and sulfuric acid from the company's smelting complex. The plant will start up in 2000. The environmental management system will be 75% complete by December 1999. The environmental measures include the following:

- Environmental impact assessment at each relevant location.
- Consultation with government agencies and local communities.
- Risk assessments prepared for all major impacts.
- Regular community visits to the smelter plant.
- Information sheets.
- Cultural heritage management plan.
- Waste minimization plan.
- Consultation with the port community about increased traffic.

**Conclusions**

The IFA/UNEP publications are devoted to the environmental aspects of the fertilizer industry. They are relatively short and written in layman’s language. New editions can be prepared at low cost.

The publications explain what the fertilizer industry is and does, its importance, and its responsible approach to environmental matters. These publications may help to correct some misconceptions. We hope that they are discreetly improving the image of the fertilizer industry. Certainly the demand for these publications has exceeded our expectations.

Although most fertilizer producers today have efficient and nonpolluting plants, some fertilizer manufacturing operations are not yet up to standard. The publications demonstrate what is being done by other manufacturers.

With modern technology, emissions from fertilizer plants can be reduced to acceptable levels. However, there is still much to be achieved regarding the efficient distribution and use of mineral fertilizers. These problems are analyzed in other IFA/UNEP publications.

UNEP's environmental program concerns sustainable production and consumption. In this context, we are expanding the IFA/UNEP Environmental Series of reports by covering the whole cycle from factory to farm. In addition to *Mineral Fertilizer Production and the Environment*, other publications already issued are:

- *The Fertilizer Industry, the Environment and World Food Supplies.*
**Introduction**

An ever-more-complex environmental agenda in an increasingly global society is leading to some major shifts in the way environmental issues are regulated, with governments using more varied policy and regulatory instruments, and community action also increasingly influencing industry practices.

There is now also a much wider appreciation by industry of the advantages of voluntary measures such as codes of practice and negotiated performance targets, as these can help improve the environmental performance of the entire industry sector ahead of regulations and international conventions. Although voluntary codes rarely contain fixed targets or detailed action plans, they define a common approach for the industry as a whole concerning the management of issues, and thus provide an agreed-upon practical framework within which environmental problems can be resolved. Increasingly, regulations and conventions are incorporating industry codes and guidelines within the implementation measures to be applied.

Some of the industries within which national or international associations have developed voluntary environmental codes include chemicals, mining, iron and steel, and tourism. Their codes are frequently based on forward-looking policy statements by leading companies in their sector. This paper discusses the status of voluntary codes generally, with a view also to potential application in the fertilizer sector. The information is based on two recent UNEP publications concerning the use of voluntary instruments and environmental codes by industries around the world [1,2].

The UNEP publications are part of a wider program to promote environmental management practices and management tools worldwide. This includes publication of training materials for environmental management systems (EMS), analysis of trends in environmental reporting (and nonreporting), further development of assessment and evaluation tools, and organizing high-level dialogue on how to integrate sustainable development concepts into corporate management, for example, “responsible entrepreneurship.” The work has been extensively reported in UNEP publications, at the Commission on Sustainable Development (CSD), and at meetings with industry and governments.

**Codes and Their Relationship With Other Management and Regulatory Approaches**

The term “Environmental Code” refers here to a written voluntary commitment by an association or company to achieve improved environmental performance. Other terms such as environmental charter, principles, guidelines, and declaration may also be used by some organizations. The essential feature is that the instrument aims to provide a formal, agreed-upon framework for environmental action by the signatory companies or associations.

Although the use of industry codes commenced during the 1980s, the preparations for the Rio Summit in 1992 gave impetus to additional national and international codes in several
sctors. Many codes focus strongly on pollution, waste, and safety aspects. Codes that also integrate the social dimension of sustainable development are still relatively rare, although some organizations and companies are starting by promoting increased community dialogue on environmental issues.

To work effectively, codes of conduct also need to be seen in the context of other management instruments that are already in use. These include ISO 14000 (generally used by companies), environmental and social performance reporting (used by companies and less commonly by associations), cooperative programs of research and development, as in the Canadian Mine Environment Neutral Drainage 2000 (MEND) program, community outreach to local governments and individual community groups, and support for education and training on key issues. Other voluntary commitments such as greenhouse targets may also apply.

It is important to stress that codes are a complement to, not a substitute for, regulations. New regulations themselves are increasingly designed to make best use of codes that already exist and may even incorporate negotiated targets within their structure. But codes, more than other instruments, are also intended to avoid future regulations by improving environmental performance on a voluntary basis.

Overview of Codes in International Use

Within the last decade, association codes on the environment have been adopted in many industry sectors, especially those concerned with potentially polluting or hazardous activities. Here environmental principles and actions by individual companies are already common. Industry associations have generally based their sector-wide environmental codes on the examples of leading companies.

While most common in the United States, United Kingdom, Australia, Canada, and Scandinavia, we also see industry in the Philippines, Brazil, and other developing countries gradually adopting voluntary codes, often through the influence of environmental business associations and multinational corporations.

Key sectors in which we find environmental codes include chemicals, forestry, mining, and tourism, but also oil and gas, electrical power generation, fertilizer production, and less commonly, smaller industries like tanning and textiles. The chemical sector took the lead some years ago with its “Responsible Care” program. Its proactive implementation and outreach programs have ensured that it remains the largest, most widespread, and best implemented of any of the sectoral industry initiatives surveyed and retains to this day some proactive features that others have still to incorporate.

Some codes have followed the environmental guidelines prepared by the International Chamber of Commerce (ICC) in 1990 and revised for the 1992 Rio Summit. There are currently several thousand company signatories to these guidelines, and many national business associations have modeled their own guidelines on the ICC document.

Environmental codes are also increasing in the professions. The Australian and New Zealand Institution of Engineers is a leading example of this type of action. A worldwide code of environmental ethics has been prepared by the World Federation of Engineering Organizations. The International Federation of Consulting Engineers has also adopted an environmental code of ethics for its members.

Although not in the same pattern as other codes, the recent International Declaration on Cleaner Production (IDCP) should be mentioned as one of the new instruments. This Declaration is a voluntary statement of commitment to the preventive approach in environmental management, and it can be signed and implemented by companies and associations alike. Like other codes, it does not include quantitative targets but rather focuses on a commitment to promote and implement cleaner production through a range of actions and communication measures. The text of the Declaration is shown in the Appendix.

Further information on specific codes and other voluntary instruments can be found in the UNEP-IE publication on Voluntary Codes of Conduct [1].

What Do Codes Commonly Contain?

Many environmental codes include principles such as socially responsible behavior, operational responsibilities, transparency, communication, and reporting. Some propose an environmental management model for dealing with specific environmental issues. A regular feature of codes is respect for regulations and compliance. Many codes contain “beyond compliance” provisions.

Environmental issues that are explicitly mentioned tend to focus on local concerns such as reduction of pollution and emissions, minimizing risk, and improving safety. But in the post-Kyoto era, global issues such as climate change, trade in wastes, chemical contamination, and biodiversity are being in-
creasingly included in specific secondary instruments such as the “Greenhouse Challenge” program.

Some codes include proactive aspects such as:

- Explicit social as well as environmental goals.
- Life-cycle responsibility for products.
- Product stewardship and ethical positions on products and processes.
- Responsibility for contractors and suppliers.
- Assisting others to implement the code.
- Public-private partnership approach.
- Transparency in operations.
- Risk communication.
- Measurable, quantifiable targets.
- Reporting of progress.
- Technology transfer.

In terms of innovation, companies seem to be further advanced in their corporate policies than most associations, perhaps reflecting the greater possibilities for action at the corporate level.

**Implementation Mechanisms**

The area that still needs the most development is implementation. Although the more recent codes try to include concrete measures, the older codes generally require some upgrading to cover this issue. Some codes require companies to prepare public reports about progress in implementation.

Here it is useful to quote from a recent review by the European Environment Agency [3]. This review of formal environmental agreements between industry and governments is also relevant to environmental codes:

If (agreements) are to be used more widely, it is necessary to improve their credibility and accountability. This calls for setting of clear targets, for greater transparency, implementation, and evaluation, and for the introduction of reliable reporting arrangements.

It is encouraging that the associations developing the more recent codes are starting to address this point with a determination that codes should become management tools rather than a public relations statement that are never translated into action.

In an attempt to sketch out what could be contained in future codes, the attached list of examples of “best current practice” shows some of the more proactive initiatives that have been undertaken and could be encouraged on a wider basis worldwide (Table 1).

**Application of Codes to the Fertilizer Sector**

Considering the size of the fertilizer sector, the size of the companies, and the significance of the environmental challenge it faces, national and voluntary codes on environmental performance would greatly speed up the response to global and regional problems. A number of individual companies already have fully developed environmental policies and good experience with management systems and public reporting. But in international negotiations such as those on climate change, transfrontier pollution, and biodiversity, the fertilizer industry is accountable for its total performance. Unfortunately, the opinion of the regulator and of the general public, likewise, is determined by the poorest performers, not the best performers.

It is in this regard that the fertilizer industry needs a sector-wide environmental policy, code, and action plan to successfully confront the complex and interconnected environmental issues that it now faces. The environmental agenda is no longer simply addressing single issues in isolated situations. The life-cycle approach to environmental management demands contributions from a wide range of companies, institutes, and suppliers and reaches down to the level of individual farmers. Only a comprehensive sector-wide code can hope to provide a coherent and effective response.

Voluntary codes are not a gratuitous act of public benevolence. They make perfect business sense. They have positive long-term consequences that improve the cost-effectiveness of the environmental action of individual companies by providing a coherent framework for such action. By implementing voluntary agreements ahead of regulation, the weight of legal measures is reduced, especially those that might otherwise apply to the newer environmental concerns of regional or global scope. Finally, through such codes, the industry as a whole can develop in a manner that is more in harmony with the sustainable development agenda and hence will be less likely to confront public and institutional pressures after major investments have already been made.

**Conclusions**

A number of sectors in various parts of the world have developed codes of environmental conduct. Although their content and format vary widely, there is general agreement now that the development of such codes is an important component of the industry’s role in managing environmental issues responsibly.
Codes need to be developed in the context of other environmental management instruments. Voluntary codes need to complement rather than replace mandatory environmental regulation.

Codes are starting to acknowledge the broader aspects of the sustainable development agenda while continuing to address local pollution issues. The attention given by business groups to environmental management systems means that codes are also beginning to include concepts such as responsibility for damage, life-cycle stewardship, supply-chain management, public partnership, technology transfer, and risk communication, to give just a few examples.

Most current codes still need to give more attention to implementation mechanisms. This aspect will have to be improved if the gap between industry promotion of voluntary measures and public insistence on tight regulatory control is to be narrowed.

The complexity of the environmental agenda now means that the fertilizer industry, like other industries, would benefit from formalizing its voluntary actions through national and international codes on the environment. Several fertilizer companies are already in a good position to provide leadership in developing such codes. Industry associations could provide a useful start by immediately promoting UNEP’s International Declaration on Cleaner Production, which includes many of the elements needed for implementing a sector-wide code.

### References and Selected Reading


5. Engaging Stakeholders—UNEP and Sustainability:
   - (i) The Benchmark Survey—the second international progress report on company environmental reporting, 1996.

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**Table 1. Some Components of Best Current Practice in Environmental Codes**

<table>
<thead>
<tr>
<th>Code prerequisite for membership</th>
<th>Minerals Council of Australia (MAC), Responsible Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference to sustainable development</td>
<td>Mining Association of Canada (MCA), MAC</td>
</tr>
<tr>
<td>Social issues addressed</td>
<td>MCA, International Council on Metals and the Environment (ICME), MAC (Whitehorse Initiative)</td>
</tr>
<tr>
<td>Life-cycle responsibility</td>
<td>American Petroleum Institute (API), Responsible Care</td>
</tr>
<tr>
<td>Product stewardship</td>
<td>ICME, International Lead Association</td>
</tr>
<tr>
<td>Responsibility for contractors</td>
<td>MAC, MCA, International Chamber of Commerce (ICC)</td>
</tr>
<tr>
<td>Assisting others to implement</td>
<td>API, Responsible Care</td>
</tr>
<tr>
<td>Public partnership principle; transparency</td>
<td>MCA, Responsible Care</td>
</tr>
<tr>
<td>Risk communication</td>
<td>Responsible Care, ICME</td>
</tr>
<tr>
<td>Measurable targets recommended</td>
<td>MCA</td>
</tr>
<tr>
<td>Quantifiable targets in the code</td>
<td>-</td>
</tr>
<tr>
<td>Reporting of progress (by signatories)</td>
<td>MCA, ICC</td>
</tr>
<tr>
<td>Reporting of progress (by association)</td>
<td>API, report on releases</td>
</tr>
<tr>
<td>Implementation program specified</td>
<td>-</td>
</tr>
<tr>
<td>Technology transfer</td>
<td>MAC</td>
</tr>
<tr>
<td>Secondary codes for implementation</td>
<td>Many</td>
</tr>
</tbody>
</table>
We recognize that achieving sustainable development is a collective responsibility. Action to protect the global environment must include the adoption of improved sustainable production and consumption practices.

We believe that Cleaner Production and other preventive strategies are preferred options. They require the development, support and implementation of appropriate measures.

We understand Cleaner Production to be the continuous application of an integrated, preventive strategy applied to processes, products and services in pursuit of economic, social, health, safety and environmental benefits.

To this end we are committed to:

**LEADERSHIP**
- using our influence
  - to encourage the adoption of sustainable production and consumption practices through our relationships with stakeholders.

**AWARENESS, EDUCATION, AND TRAINING**
- building capacity
  - by developing and conducting awareness, education and training programs within our organization;
  - by encouraging the inclusion of the concepts and principles into educational curricula at all levels.

**INTEGRATION**
- encouraging the integration of preventive strategies
  - into all levels of our organization;
  - within environmental management systems;
  - by using tools such as environmental performance evaluation, environmental accounting, and environmental impact, life cycle, and cleaner production assessments.

**RESEARCH AND DEVELOPMENT**
- creating innovative solutions
  - by promoting a shift of priority from end-of-pipe to preventive strategies in our research and development policies and activities;
  - by supporting the development of products and services which are environmentally efficient and meet consumer needs.
COMMUNICATION

*sharing our experience*

• by fostering dialogue on the implementation of preventive strategies and informing external stakeholders about their benefits.

IMPLEMENTATION

*taking action to adopt Cleaner Production*

• by setting challenging goals and regularly reporting progress through established management systems;

• by encouraging new and additional finance and investment in preventive technology options, and promoting environmentally sound technology cooperation and transfer between countries;

• through cooperation with UNEP and other partners and stakeholders in supporting this declaration and reviewing the success of its implementation.
**NO\textsubscript{x} Abatement for Nitric Acid Plants**

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**Introduction**

Some years ago nitric acid plants often were notorious for their yellowish or even brown colored plume from the stack. This plume was caused by the nitrogen oxides in the off-gas, which now can be reduced by several processes. One of these, which can be installed as an add-on to existing nitric acid plants, is the selective catalytic reduction (SCR) process. This process was developed by BASF in the mid-1960s and went on stream at the beginning of the 1970s. So far, more than 45 nitric acid plants all over the world have installed the BASF NO\textsubscript{x} abatement process and are running it with complete success.

**Nitric Acid Process**

In nitric acid plants, ammonia is catalytically oxidized on platinum gauzes by means of air according to the following reactions:

\[
\begin{align*}
4 \text{NH}_3 + 5 \text{O}_2 &\rightarrow 4 \text{NO} + 6 \text{H}_2\text{O} \\
2 \text{NO} + \text{O}_2 &\rightarrow 2 \text{NO}_2 \\
3 \text{NO}_2 + \text{H}_2\text{O} &\rightarrow 2 \text{HNO}_3 + \text{NO}
\end{align*}
\]

The resulting nitrogen monoxide (NO) is further oxidized to nitrogen dioxide (NO\textsubscript{2}) using the residual oxygen or secondary air that is added before entering the absorption column. Finally, the nitrogen dioxide is absorbed in water to form nitric acid (HNO\textsubscript{3}). The NO formed by this step has to be oxidized and absorbed by repeating the last two steps as long as its concentration is high enough to do so.

Depending on the plant design and the mode of operation, the tailgas after absorption contains variable amounts of nitrogen monoxide and dioxide (NO\textsubscript{2}). The total NO\textsubscript{x} content can be as high as 2,500 ppm. In some cases even higher concentrations are experienced. The molar ratio of NO\textsubscript{2} to the total NO\textsubscript{x} is generally referred to as the degree of oxidation, which can reach 50%, or even more in nitric acid plants.

**Decreasing Nitrogen Oxide Emissions**

In contrast to power stations, the nitrogen oxides in the tailgas of nitric acid plants consist of NO\textsubscript{2} to a significant extent. The NO\textsubscript{2} is deep purple when concentrated and reddish brown or yellow when it is diluted with air even up to an air-to-NO\textsubscript{2} ratio of 10,000 or more.

Historically, these plants were already the focus of attention in the 1960s because the NO\textsubscript{2} emitted gave their off-gases a brown color. In the beginning, the main focus was on the removal of the color, for example, by reacting the NO\textsubscript{2} with carbon monoxide (CO). Later, measures were considered both for removing the color from the off-gas and for decreasing the high NO\textsubscript{x} content.

There are several measures for decreasing the NO\textsubscript{x} content of the off-gas, including improvement of the NO\textsubscript{x} absorption, downstream alkaline absorption, catalytic combustion, and selective catalytic reduction by ammonia.

The improvement of NO\textsubscript{x} absorption can be achieved by the following methods:

- Extending the absorption volume.
- Increasing the absorption pressure.
- Lowering the absorption temperature.
- Using specially designed absorber trays.

There are advantages and drawbacks to these methods, but the subsequent adoption of these improvements to an operating plant could virtually correspond to the construction of a new plant.

Downstream alkaline absorption is a method that has proven useful in practice. For example, an NO\textsubscript{x} content of from 600 to 800 ppm in the off-gas can be decreased to less than 200 ppm if the degree of oxidation of the off-gas is in the range of 40%-60%. Another precondition is that the resulting alkaline solu-
tion can be put to use. The chemistry of this process is as follows:

\[ \text{NO} + \text{NO}_2 + 2\text{NaOH} \rightarrow 2\text{NaNO}_2 + \text{H}_2\text{O} \]
\[ 2\text{NO}_2 + 2\text{NaOH} \rightarrow \text{NaNO}_2 + \text{NaNO}_3 + \text{H}_2\text{O} \]

To achieve catalytic combustion, a gaseous fuel (e.g., hydrogen or natural gas) added to the off-gas at the ignition temperature burns, using the remaining oxygen in the tailgas. When all the oxygen has been consumed, the fuel reacts catalytically with nitrogen dioxide, decomposing it to nitrogen monoxide first and then in a second step to nitrogen, forming carbon dioxide and water. The reactions follow:

\[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \]
\[ \text{CH}_4 + 4\text{NO}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + 4\text{NO} \quad \text{(catalyst)} \]
\[ \text{CH}_4 + 4\text{NO} \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + 2\text{N}_2 \quad \text{(catalyst)} \]

Apart from the substantial consumption of fuel, there may be problems with secondary emissions of carbon monoxide, unburnt methane, and other byproducts including ammonia and even hydrocyanic acid. Further, this system is not available as an add-on system for existing plants because the need for a high-temperature gas expander would require a complete restructuring of the heat recovery system.

The process of selective catalytic reduction by ammonia uses gaseous ammonia to catalytically reduce the NO and NO\(_2\) to harmless nitrogen and water vapor. The following three chemical reactions mainly govern the selective catalytic reduction of nitrogen oxides in the tailgas of nitric acid plants:

\[ \text{NO} + \text{NO}_2 + 2\text{NH}_3 \rightarrow 2\text{N}_2 + 3\text{H}_2\text{O} \quad \text{(catalyst)} \]
\[ 4\text{NO} + \text{O}_2 + 4\text{NH}_3 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O} \quad \text{(catalyst)} \]
\[ 6\text{NO}_2 + 8\text{NH}_3 \rightarrow 7\text{N}_2 + 12\text{H}_2\text{O} \quad \text{(catalyst)} \]

The rates of these reactions vary significantly and increase with temperature and pressure. Detailed laboratory studies reveal that the first reaction is the one that is predominantly responsible for the degradation of nitrogen oxides, NO and NO\(_2\). Concerning the reaction with ammonia, nitrogen dioxide reacts more slowly than does nitrogen monoxide. This behavior results in a characteristic shape of the curve representing the NO\(_x\) degradation, depending on the degree of oxidation (Figure 1). As the degree of oxidation increases, the NO\(_x\) degradation is maximized depending on the catalyst used.

**BASF's Experience With NO\(_x\) Abatement**

At the end of the 1960s, BASF pioneered the development of the SCR process for the catalytic reduction of nitrogen oxides with ammonia. The first BASF catalyst, named O4-80, was an extrudate catalyst using V\(_2\)O\(_5\) as active material on an alumina carrier. It works in the temperature range of 200°-380°C when the degree of NO\(_x\) oxidation is in the range of 20%-60%, which is typical in most nitric acid plants. Thus, it has been used in many medium- and high-pressure plants, decreasing the NO\(_x\) content from as much as 2,000 ppm to as little as 50 ppm or even less.

This catalyst has matured into the extrudate catalyst O4-81 and the honeycomb catalyst O4-82. Catalyst O4-81 is more active and can be used at temperatures even lower than 170°C. The particular benefit of switching to this catalyst in existing plants is that the NO\(_x\) content is lowered without changing the abatement reactor. This is of great advantage, especially when the degradation of the NO\(_x\) has to be improved owing to either an increase in capacity or to meet increasingly stringent emission levels. Another advantage of the O4-81 catalyst is that it degrades NO\(_x\) even at an oxidation degree of 80% or more. Data for the three catalysts are given in Table 1.

The pore volume and the BET surface area of the titania-based BASF catalyst O4-81 are evidently higher compared with the
This substantially larger surface area and the larger pore volume, combined with a suitable distribution of the active component, are responsible for the increased catalytic activity of BASF catalyst O4-81.

The honeycomb catalyst O4-82 is used in low-pressure reactors installed in nitric acid plants downstream of the expansion turbine when an installation on the pressure side is not feasible. The main advantage of the O4-82 catalyst is the very low pressure drop; thus, the efficiency of the turbine is not diminished.

All three catalysts exhibit a high operating flexibility and long-term stability, enabling plant operators to reliably comply with emissions standards. The life of the catalysts depends on the impurities in the gas that may poison the catalyst. Deposits of salts or organic carbon have to be excluded. Alkaline droplets or some silicon compounds may also have a deactivating effect. In normal nitric acid plants the expected life of the catalyst is 5-10 years, but we know many abatement systems running successfully for more than 15 years without needing to replace the BASF catalyst.

One of the possible unwanted side reactions of the SCR process is NH₃ reacting with oxygen to form N₂O. This is especially important because N₂O in recent years has been considered an air pollutant that is also partly responsible for the greenhouse effect. This reaction becomes relevant in the temperature range of 300°-350°C or more, depending on the catalyst used.

It should be emphasized that, when operated in the recommended temperature range, these BASF catalysts for NOₓ abatement do not form N₂O, which would result in unwanted secondary emissions. On the other hand, no N₂O will be destroyed in contact with these catalysts, and thus they cannot be used for diminishing the N₂O content in the off-gas of nitric acid plants. BASF is currently doing very intensive work on this subject. For instance, BASF has developed a catalyst for the destruction of N₂O that can be used at temperatures as high as 900°C. This means the catalyst can be installed immediately beyond the platinum gauges. This catalyst has been running in an industrial-scale test for about 3 months, reducing the N₂O content in the gas by 80%-90%.

Figure 2 shows how the BASF NOₓ abatement process (DENOX) can typically be integrated in a nitric acid plant. In all medium- or high-pressure plants, the tailgas leaving the absorption tower is heated in a heat exchanger before entering the expansion turbine to give high energy recovery. This temperature is high enough for NOₓ reduction by these BASF catalysts. So the ideal place for installing the SCR reactor is on the high-pressure side upstream of the stack.

Figure 2. NOₓ Abatement for High-Pressure Nitric Acid Plants.
tailgas turbine. A photograph of a high-pressure NOx abatement facility is shown in Figure 3.

In low-pressure nitric acid plants, the conditions are entirely different. For effective NOx absorption, the temperature is kept as low as possible. In general, the tail gas from a low-pressure absorption unit is less than 50°C, so it has to be heated to generate a temperature sufficient for starting the SCR reaction. This can be done by steam, by an external gas burner, or by means of an electric heater. In all cases, a heat exchanger should be used between cold raw and hot cleaned tailgas to save energy.

In older nitric acid plants there is an additional problem: To decrease the NOx content in the off-gas, many of them are equipped with an alkaline washing system, which results in alkaline mist in the off-gas. Sometimes the droplets are so small that even an aerosol demister would not effect complete separation. The remaining alkaline liquor in the gas stream quickly reduces the activity of the catalyst.

The low-pressure nitric acid plant at BASF in Ludwigshafen is such a plant equipped with an alkaline washing system. Built in 1915, it was one of the first nitric acid plants in the world. It was rebuilt in 1948 after World War II and was equipped with an alkaline washing system that is used for cleaning the off-gas and for producing sodium nitrite solution as well. The off-gas, even after being washed with caustic, had an NOx content of more than 1,000 ppm. This was much more than specified in the German environmental regulation “TA Luft” where the tolerable NOx content in the tail gas from nitric acid plants is 220 ppm. The tailgas also has to be colorless. Therefore, BASF started investigations in 1989 to determine how to add an SCR NOx abatement facility to its low-pressure plant.

Very soon it was clear that the honeycomb catalyst O4-82 should be used. This catalyst meets the specific requirements of such a low-pressure plant. First, it exhibits a high activity even at a temperature as low as 170°C; this means that the off-gas can be heated by waste steam, which is much less expensive than all other alternatives. Second, it causes a very low pressure drop, so that the available pressure of the gas is sufficient without the need for an additional booster. Finally, it is insensitive to dust that might be deposited on its surface, i.e., there is no increase in pressure drop and no decrease in activity as a result of dust deposits.

Concerning the poisoning of the catalyst O4-82 by alkaline droplets, it was found that the damage is caused by wet droplets only. After the water has been evaporated, the dry alkaline dust will not harm the catalyst. Therefore, the problem was solved by drying the droplets without deposits being formed on the walls, pipes, or fittings or on the heat exchanger. This was done by feeding back some of the hot gas from the steam heater outlet to the cold gas containing the alkaline droplets, heating them up, and evaporating the liquor without making contact with the walls. The flow diagram of the process is shown in Figure 4.

The start-up of the abatement system was very smooth. Only a few minutes after starting the

![Figure 3. Photograph of a High-Pressure NOx Abatement Facility.](image-url)
ammonia feed, the NO\textsubscript{x} content of the tailgas decreased to values of less than 200 ppm. By monitoring the NO\textsubscript{x} content of the off-gas, ammonia is controlled automatically even when the raw NO\textsubscript{x} content varies considerably.

When the NO\textsubscript{x} content in the raw gas increases from 550 to more than 1,100 ppm, the NO\textsubscript{x} content in the cleaned gas stays nearly constant at an average of 185 ppm. The ammonia slip is less than 1 ppm.

This system, shown in Figure 5, has been running for more than 6 months without malfunction. Our experience suggests that this system will continue running, using the BASF catalyst without problems for 5-10 years or more. This catalyst life is usual with all BASF abatement systems installed in medium- or high-pressure plants.

**Conclusion**

After having gained this experience, BASF is now able to license the NO\textsubscript{x} abatement system for low-pressure plants. This will be another step forward in environmental work for cleaning the off-gas from low-pressure nitric acid plants with or without alkaline washing towers. As a result, BASF now has NO\textsubscript{x} abatement systems available for all processes used for nitric acid production. A list of plants utilizing the BASF SCR process is shown in Table 2.
Table 2. List of Plants With the BASF SCR Process Installed

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Capacity (mtpd)</th>
<th>Nitric Acid (NO\textsubscript{x} ppm)</th>
<th>Uncleaned Tailgas (NO\textsubscript{x} ppm)</th>
<th>Cleaned Tailgas (NO\textsubscript{x} ppm)</th>
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Phosphogypsum Disposal and the Environment

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Introduction

For every metric ton of P\textsubscript{2}O\textsubscript{5} produced as phosphoric acid using the wet process, from 4.5 mt to more than 5.5 mt of phosphogypsum is generated, depending on the quality of the phosphate rock. Based on 1996/97 estimates of the International Fertilizer Industry Association, more than 22 million mt of phosphoric acid (as P\textsubscript{2}O\textsubscript{5}) is produced annually worldwide, generating in excess of 110 million mt of gypsum byproduct.\(^1\) The free water in the gypsum cake from the filters is highly acidic, having a pH as low as 1.0. Commercial uses in agriculture and in manufacturing gypsum board and Portland cement consume only a very small percentage of this byproduct; the vast majority is disposed of on land in gypsum stacks or is discharged into water bodies.

Properties of Phosphogypsum

Physical Properties

Depending on the reaction temperature used to produce phosphoric acid, calcium sulfate in either the dihydrate form (CaSO\textsubscript{4}•2H\textsubscript{2}O) or the hemihydrate form (CaSO\textsubscript{4}•½H\textsubscript{2}O) is generated as a byproduct filter cake. The gypsum cake, from the filtration step, usually has a free moisture content between 25% and 30%. In the presence of free water, hemihydrate will, fairly rapidly, convert to dihydrate (gypsum) and in the process, if left undisturbed, will set up into a relatively hard cemented mass. Dihydrate consists of relatively soft, principally silt-size (<0.075 mm) aggregates of crystals, the morphology of which depends on the source of the phosphate rock and the reactor conditions.

Typical engineering properties of phosphogypsum can be found in Wissa [1,2]. Properties, such as density, strength, compressibility, and permeability (hydraulic conductivity), are not only functions of the rock source and reaction process, but also are attributable to the method of deposition, age, location, and depth within the landfill or stack in which the gypsum is placed. The deeper the gypsum is within a stack and the older the stack, the higher its density and strength and the lower its compressibility and permeability, provided solution channels and cavities have not developed in the stack as a result of rainfall infiltration.\(^2\)

Chemical Properties

Phosphogypsum consists primarily of calcium sulfate dihydrate with small amounts of silica, usually as quartz, and unreacted phosphate rock. Radium and uranium, as well as minor amounts of metals considered toxic by the U.S. Environmental Protection Agency (EPA), namely, arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver, along with phytotoxic fluoride and aluminum, are also present in phosphogypsum and its pore water. The concentrations of the heavy metals and radionuclides depend on the composition of the phosphate rock feed. The concentrations of constituents in phosphate rock, phosphogypsum, and process water (i.e., free water in gypsum stacks and cooling ponds) from central Florida have been reported by Garlanger [3].

Environmental concerns, more perceived than real, have developed in the last 10 years because of the presence of the trace toxic metals and radionuclides in phosphogypsum and its pore water. As a result, its use, transportation, and storage, as well as that of the associated ponds that

\(^1\) Based on 1996/97 estimates supplied by Mr. Keith Isherwood of the International Fertilizer Industry Association.

\(^2\) In rainwater, gypsum is two orders of magnitude more soluble than calcium carbonate (the most soluble component of limestone); therefore, a gypsum stack will in a matter of a few years develop typical Karst features if left uncapped and unused.
contain process water at pH values below 2, are regulated in the United States by state agencies such as the Florida Department of Environmental Protection (FDEP) [4] and/or the U.S. EPA [5].

Disposal Options

Worldwide, four methods are being used by the phosphate industry to dispose of surplus phosphogypsum: (1) discharging to water bodies, (2) backfilling in mine pits, (3) dry stacking, and (4) wet stacking.

The term “dry stacking” (as it applies to conveying or hauling and stacking) means that the gypsum is transported and stacked at the same moisture content as when it discharges from the filter. The term is somewhat misleading because the actual moisture content is typically between 20% and 25%. “Wet stacking” involves pulping the cake with additional water to form a slurry that can be pumped or hydraulically transported to a disposal area. For the sake of completeness, all four of the methods are described in the following sections even though environmental aspects of only the dry and wet stacking options will be addressed.

Discharging to Water Bodies

A relatively small number of phosphoric acid chemical plants discharge their phosphogypsum directly to a receiving water body. These include major producers in Morocco, where the gypsum cake is slurried with seawater and discharged into the Atlantic Ocean. Although discharging waste gypsum as a dilute slurry into very large open water bodies with strong currents and tides off uninhabited coasts is the most economical disposal option, and may be politically and environmentally acceptable, discharging gypsum into rivers and smaller bodies of water, such as the Mediterranean Sea, is no longer politically acceptable.

Most existing phosphoric acid plants, and those currently under construction or in the planning stage, are not located near suitable water bodies to allow for disposal of their gypsum byproduct in the sea, and disposal on land is the only economically viable option. Therefore, this paper will be limited to the environmental aspects of land disposal.

Gypsum Tailings Blending

The pits created from mining phosphates at PCS Phosphates in North Carolina (United States) are being reclaimed by backfilling with a blend of phosphatic clay tailing from the rock beneficiation process and phosphogypsum obtained directly from the phosphoric acid plant filters. This is environmentally acceptable because the high calcareous content of the clay in the ore at that mine neutralizes the acid remaining in the gypsum cake after filtration. PCS Phosphates has a unique set of hydrogeologic conditions that are not likely to be present anywhere else.

Because of its relatively high solubility, high compressibility, and radioactivity, phosphogypsum is generally not recommended as structural fill for land reclamation, especially if the land will be used for housing.

Wet Stacking

Wet stacking is by far the most popular phosphogypsum land disposal method. This method involves pulping the gypsum cake as it comes off the filter with either freshwater or seawater and pumping the slurry through a pipeline to a gypsum disposal area where the solids are allowed to settle out as shown in Figure 1. Clarified excess water is decanted and, for a freshwater system, pumped back to the plant for reslurrying gypsum and reuse in the process. With time, the recirculated process water usually reaches an equilibrium pH between 1.3 and 2.0, depending on the process and climatic conditions. The soluble P$_2$O$_5$ content of the acidic process water is typically between 10,000 and 15,000 mg/L but can be as high as 20,000 mg/L.

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3. Moisture content herein is defined as $w_w/(w_g+w_w)$, where $w_g$ is the weight of dry gypsum (CaSO$_4$$\cdot$$2$H$_2$O) and $w_w$ is the weight of free water in the gypsum cake.
When seawater is used to slurry the gypsum, the clarified seawater is not returned to the plant for reuse but is discharged back to the sea. When seawater is the carrier, the slurry is usually very dilute (about 5% solids by weight), and the pH of the water being discharged is above 2.0. Several plants, namely in Greece, Spain, Mexico, and Tunisia, have considered or are considering eliminating the use of seawater and converting to closed-circuit freshwater systems. Slurry concentrations between 20% and 30% by weight are commonly used in closed-circuit water systems. It should be noted that when a gypsum stack is converted from a seawater to a freshwater system, unless special provisions are taken to reduce contamination, the return water to the plant from the stack will be, at least initially, high in chlorides due to leaching of the old gypsum. This can cause corrosion problems.

Operation of the gypsum stack typically uses elevated rim ditching (Figure 2) and/or spigots (Figure 3) and the upstream method of construction to raise the perimeter starter dikes with gypsum [1]. Draglines are being phased out and are being replaced with backhoes and hydraulic excavators to construct and raise the gypsum starter dikes and rim ditches, as shown in Figure 4. A small dozer is needed, usually part-time, to level the gypsum excavated from the rim ditches to raise the starter dikes.

Where freshwater is available at a reasonable cost, a wet stack is much easier and more reliable and economical to operate than a dry stack. It also has the additional economic benefit of improving process P₂O₅ recovery. Unlike dry stacking, wet stacking does not involve construction around the clock and can be operated with much less equipment and personnel. Dusting is generally not a problem because construction traffic is limited to the stack access road and the perimeter and interior partition dikes, which cover relatively limited and defined areas that can easily be kept damp.

Most plants that produce dihydrate gypsum use the wet stacking disposal method. Moreover, several plants that produce hemihydrate, including the Swift Creek Plant of PCS Fertilizer in Florida and the PCS Nitrogen Plant in Louisiana, also use wet stacking. At these plants, conversion to dihydrate is not complete by the time the slurry reaches the stack; nevertheless, the stacks are managed and raised using the same methods.

![Figure 2. Gypsum Slurry Being Discharged From an Elevated Rim Ditch Into the Settling/Clarification Pond on Top of a Stack.](image-url)
Figure 3. Valving Used to Distribute Gypsum Slurry by Spigotting From a Pipeline Around the Perimeter of a Stack.

Figure 4. A Truck-Mounted Hydraulic Excavator Constructing the Perimeter Dike With Gypsum Excavated From an Elevated Rim Ditch.
and equipment used for gypsum from dihydrate plants.

In a closed-loop recirculation system, any soluble material introduced with the gypsum or with the makeup water will increase in concentration until equilibrium is reached, whereby the material is removed from the system at the same rate it is introduced. In many systems, this means that a purge stream is required to prevent the concentrations from exceeding specified operating levels. For wet stacking, purging of the cooling tower or cooling pond circulation water is unnecessary because, inherently, natural purging continuously occurs as a result of water being held in the pores of the gypsum as it is added to the stack.

Dry Stacking

Worldwide, dry stacking is being used much less frequently than wet stacking for phosphogypsum disposal. In dry stacking, the gypsum cake from the filter is transported to the disposal area without adding water to the gypsum cake. Typically, the gypsum, which after filtration has a free moisture content of about 25% by dry weight, is transported to the disposal area by trucks or a belt conveyor. At the disposal site, dozers, with or without a mechanical stacker (Figure 5) and movable lateral conveyors (Figure 6), are used to spread the gypsum. In Jordan, disposal by dry stacking is being used at Aqaba for dihydrate and at Eshidiya for hemihydrate. It is also used in Tunisia, Senegal, and several former Soviet Union countries.

Transport Options

Two basic options, each with subsets, are used to convey the gypsum from the loading station at the phosphoric acid plant filters to the disposal site, namely, “dry” transportation and hydraulic or “wet” transportation. As with dry stacking, the term “dry transportation,” as it applies to conveying or hauling, means that the gypsum is transported to the disposal site at the same moisture content as when it discharges from the filter. Wet or hydraulic transportation involves pumping through a pipeline using either freshwater or seawater to pulp the gypsum cake.

Dry Transportation

Dry transportation can be achieved by one or a combination of the following methods: (1) mechanical conveyors,
(2) trucks, (3) railroad cars, and (4) barges and bottom dumping scows.

**Mechanical Conveyors**—At the loading station, the dewatered gypsum cake from the belt filters is transferred by a belt conveyor transport system to the disposal site (Figure 7). Upon reaching the disposal site, the gypsum is spread and stacked dry, using mechanical stackers or movable belt conveyors and dozers.

**Trucking**—For trucking, the dewatered gypsum cake discharging from the filters is transferred onto a short belt conveyor. Loading the stacking trucks from the conveyor can be accomplished by several methods. Some alternatives may include feeding one or two bins that unload to the trucks, feeding a reversing cross conveyor that feeds the trucks, or loading the trucks from a diverter chute at the discharge of the conveyor. Truck drivers can control the changes in direction such that when one truck is full the driver actuates a control switch that reverses the conveyor to begin filling the next truck (Figure 8).

**Railroad**—If the phosphate rock is transported to the plant by rail from an open pit mine, only a portion of the gypsum generated can be returned to the mine and used to backfill the pits because the volume of gypsum generated exceeds the volume of the phosphate rock feed. This use would only be feasible if the hydrogeological conditions at the mine were such that the gypsum fill would not cause groundwater contamination or if measures were taken to prevent contamination. Loading the railroad car can be achieved in the same fashion as with trucks. To prevent spillage, bottom-emptying rail cars should not be used because they complicate unloading and increase the cost.

**Barging**—If the chemical plant has access to a navigable waterway into which the phosphogypsum cannot be directly discharged, bottom-dumping scows (ships) can be used to transport the gypsum to the open ocean for disposal. At the loading station, the dewatered gypsum cake from the belt filters is transferred onto a belt conveyor transport system, similar to the one used with trucks, that discharges directly into the scows.

**Wet Transportation**

Wet or hydraulic transport is by far the most widely used alternative worldwide. It is used with wet disposal on land and with direct disposal in water bodies. The gypsum cake, which comes directly from the filters, is pulped with either the process wash water or seawater to produce a slurry containing 5% to 30% gypsum. The gypsum slurry is usually conveyed by gravity through a launder or pumped to an agitated surge tank from
which it is pumped through a rubber-lined steel or high-density polyethylene (HDPE) pipeline to the on-land disposal site or to the receiving water body. With on-land disposal, the wet stacking methodology is then used to develop and operate the gypsum stack.

Two gypsum slurry pipelines (one being a spare) and one return water pipeline (or return water ditch) are usually used. To limit the hydraulic pressure in the slurry lines to about 10 bar, booster pump stations may be located at several points along the pipeline route and one near the base of the gypsum stack to deliver the slurry to the top of the stack.

**Air Emissions**

**Particulate Matter**

Phosphogypsum cake that is left undisturbed to dry will form a thin, fragile crust on its surface that is resistant to wind erosion. However, when the dried surface is mechanically disturbed by vehicle traffic and/or wind erosion, fugitive emissions of respirable particulate matter, i.e., particulate matter less than 10 mm in diameter or PM-10, can be generated from gypsum stacks and from dried spillage off conveyor belt systems, trucks, or railroad cars.

Dusting during conveyance is not a problem because the gypsum cake is moist. However, spillage of gypsum off the conveyor belts and at transfer points does occur. A high-pressure water sprayer can be used on the underside of the conveyor to wash the belt at its discharge end to remove any gypsum that may adhere to it. The wash water from the sprayer must be collected and consumed or appropriately treated and discharged. To control fugitive dust from gypsum spillage that dries out, the belt conveyor can be enclosed.

The environmental problems associated with spillage off conveyor belts can be minimized by using a proprietary type of belt conveyor, the “Foldbelt” (or equivalent), to convey the gypsum from the loading station to the disposal site. After being filled, the foldbelt-type conveyor folds the side of the rubber belt over the material, thus encasing it in an oval rubber tube until the tube opens again to discharge the material. The empty belt returns folded, thus preventing one of the major causes of spillage, i.e., material falling off the returning belt. Although this type of conveyor is considerably more expensive than conventional conveyors and has not been used with phosphogypsum, it probably would eliminate other measures that might be needed to prevent unavoidable spillage from conventional belt conveyors.

Belt conveyors are high-maintenance transportation systems, especially when handling phosphogypsum filter cake, which is a highly corrosive material that tends to liquefy at a relatively high moisture content (i.e., during reaction startup). As a result, to accommodate conveyor downtime for maintenance and repairs, a lined emergency dump area should be located at the loading station, where gypsum cake from the plants can be temporarily stored. A diverter and bypass conveyor to the emergency dump area can be activated automatically when the conveyor to the disposal site is down. A front-end loader can then transfer the gypsum from the emergency dump area to the conveyor as time permits. As long as the gypsum collected in this area is moist, it will not generate dust, and its surface will develop a thin, fragile, erosion-resistant crust upon drying. However, dust is generated when the gypsum is disturbed or moved. Spraying with water is effective in controlling dusting.

In dry stacking, the top surface of the stack is continuously disturbed by the equipment used to place and spread the gypsum. Except in locations with very high rainfall (such as Santos, Brazil, which receives 3 m of rain annually), where the surface of the stack never gets a chance to dry out, dust generated by construction equipment is a problem that can be controlled by limiting the size of the active gypsum placement area and/or haul roads and keeping their surface damp by spraying with water as needed.

With wet stacking, the containment starter dikes are best constructed with wet gypsum, using draglines or hydraulic excavators so that dust is not generated during excavation and shaping. Only the maintenance and access roads, which are subjected to construction traffic, are susceptible to dusting, but they can readily be kept damp to control particulate emissions.

**Fluorides**

Fluoride emissions from phosphogypsum pond water surfaces are primarily hydrogen fluoride (HF) and have been measured to be in the range of 0.01 to 0.10 kg/ha/day [6,7]. Fluoride emissions from dry gypsum surfaces are associated with fugitive gypsum dust. The fluoride emissions can be significantly reduced if fluosilicic acid is extracted during the production of phosphoric acid when wet stacking is used and if fugitive dust is controlled on dry stacks.

Vegetation very close to a gypsum stack can contain elevated levels of fluorides, which can cause fluorosis if ingested by cattle for a number of years.

**Radon and Radium**

Radon flux has been measured from the surface of several existing phosphogypsum stacks in central Florida [8,9,10]. The
mean flux from stacks, side slopes, and roads was essentially identical and averaged 23 picocuries/s/m². The flux level from areas that were periodically ponded averaged 2 picocuries/s/m². Radon, being a gas with a very short radioactive half life, is generally not an environmental issue.

Radon concentrations for phosphogypsum depend on the composition of the phosphate rock used in the process. In the studies previously cited [8,9,10], radium concentrations for central Florida phosphogypsum of 20 to 30 picocuries/g were measured. Phosphogypsum from other rock sources can have even lower radium concentrations. For example, the radium concentration in gypsum from North Florida rock is below 10 picocuries/g, the U.S. EPA threshold for agricultural uses, and some of that gypsum is used in peanut farming. Radium impacts can be avoided by controlling fugitive particulate emissions.

**Seepage and Other Process Water Discharges**

**Groundwater Contamination**

Evaluation of the impact on groundwater due to unlined phosphogypsum disposal sites in Florida by Wissa and Fuleihan [11], the U.S.EPA [12], and U.S. Geological Survey [13] has shown that heavy metals and radionuclide in the seepage from these facilities are effectively attenuated by the fine-grained soils and calcareous strata upon which most of these facilities are founded. Nevertheless, in 1993 the FDEP [4] promulgated rules requiring that all new phosphogypsum stacks have an impervious bottom composite liner system, consisting of a 1.5-mm thick, HDPE geomembrane in combination with either a compacted clay layer beneath it or a compacted gypsum layer over it [14]. Fuleihan and Cameron [15] discuss design details for a project in Florida (Figure 9), which established design criteria that were essentially adopted by the FDEP.

The FDEP rules require that, unless it is demonstrated that the impact on groundwater will be contained indefinitely within the property line or within a designated zone of discharge, gypsum stacks and associated process water ponds at all phosphoric acid plants in Florida be retrofitted by March 2001 to contain any groundwater plume, or be closed and replaced by new lined facilities. The rules covering closure require that the top of the stacks be covered with a liner and the side slopes vegetated.

Ardaman is currently working on retrofitting several existing wet gypsum stacks in Florida to bring them into compliance with the FDEP rules. Several approaches are being taken, depending on site-specific and operating conditions. In some situations, a vertical hydraulic barrier, consisting of a soil-bentonite cutoff wall in combination with pressure-relief wells, is being built around the perimeter of the site. In other cases, the top of the existing gypsum stack will be lined with an HDPE geomembrane (Figure 10), and then wet gypsum stacking will continue on top of the liner. To achieve the required side slope stability for the new stack on top of the liner, an underdrain system will be constructed on top of the liner around the perimeter, beneath the future outer slope of the stack.

In all but very arid climates, dry stacking does not eliminate acid water seepage from the base and toe of the slope of the stack. In desert climates where dry stacking is sometimes used without an impervious bottom liner, the potential for groundwater contamination can also exist during relatively rare heavy-rainfall events because vertical cracks frequently occur in such stacks as a result of self-weight differential settlements and/or
the low stability of the side slopes. The impact can be minimized by filling in with gypsum to prevent rainfall runoff from entering and filling the cracks, seeping deep into the stack, and reaching the underlying aquifer. This measure also avoids possible slope instability caused by hydraulic pressures generated by any water-filled cracks.

**Discharges to Surface Waters**

With closed-circuit wet stacking, all rain falling on top of the stack can be contained in the gypsum slurry settling ponds, provided that the gypsum starter dikes around the ponds have sufficient freeboard. A ditch or channel usually surrounds the stack and retains rainfall runoff contaminated from contact with nonvegetated gypsum side slopes and any lateral seepage at the toe of the stack. In wet climates, excess water in the ditch or channel, which may also serve as a process water cooling pond, is either returned to the chemical plant as process makeup water or pumped to the top of the stack for storage and eventually either consumed or discharged to receiving water bodies after appropriate treatment.

Treatment of excess process water not stored and/or consumed in the process usually consists of two-stage lime neutralization and clarification. This treatment process is expensive and requires clarification ponds in which the lime sludge is stored. The treated water is also high in dissolved solids and sulfate and sometimes ammonia in situations where nitrogen-based fertilizers are manufactured and not air stripped. For noncontact water that is not highly impacted, reverse osmosis can be used in lieu of liming.

The quantity of excess process water needing to be treated and discharged can usually be reduced, and possibly even eliminated, by having adequate surge capacity and by the way the gypsum stack and chemical plant are operated [16]. For example, amending and vegetating the bare gypsum stack slopes can, with time, prevent rainfall from coming into contact with and getting contaminated by the gypsum, thus enabling side-slope runoff to be segregated and discharged off-site without treatment. Florida recently expanded its rules, which became effective in July 1999, requiring all phosphoric acid producers in the state to annually prepare and submit to the FDEP their process water balances and the operating and water management plans for their phosphogypsum disposal facilities.

With dry stacking, runoff from the stack can be collected on-site and consumed in the chemical process or used to abate dusting by wetting trafficked areas.

**Gypsum Stack Closure**

When the storage capacity of a gypsum stack is exhausted or when a phosphoric acid chemical plant is permanently closed, seepage from the stack and rainfall runoff from the slopes have to be contained on-site and/or treated before discharge. This will continue as long as water infiltrates the stack and/or until the water in the pores of the gypsum in the stack has drained out. In addition, with time, rainfall seeping into the stack will produce a network of solution cavities that could make it more expensive to cap the top of the stack at a later date.

Regrading and vegetating the side slopes, after amending the surface with dolomitic limestone if needed, may often be sufficient to prevent rainfall (and snow melt) from seeping into the slopes and allow for slope runoff to be discharged off-site without treatment. Under favorable climatic conditions and hydrogeological settings, regrading the top of a gypsum stack to promote surface runoff, in combination with good vegetation and/or a relatively impervious clay cover, may be sufficient to prevent rainfall infiltration. In other situations, an impervious geosynthetic liner may be needed.

Once closure has been completed (Figure 11) and infiltration into the stack has been elmi-
nated, the stack will continue to drain until it stops settling due to self-weight consolidation and creep and until the moisture in the gypsum pores reaches field capacity. The time required for a closed stack to stop draining depends on the dimensions and age of the stack, the properties of the gypsum, and the hydrogeological setting [17]. A stack on a porous foundation will drain much more rapidly than one constructed atop a low-permeability clay stratum.

Conclusions

Even though considerable research has gone into finding commercial uses for phosphogypsum, more than 95% of the gypsum generated annually in the production of phosphoric acid using the wet process still has to be disposed of on land or in the sea. As a result, in the last 25 years, methods for constructing, operating, and closing gypsum stacks and associated process water ponds have been developed that enable manufacturers to achieve on-land phosphogypsum disposal in an environmentally sound manner. New disposal facilities are being permitted and constructed, and existing facilities are being retrofitted to meet stricter environmental standards.

References


Preface

Stamicarbon was established in 1947 and is the wholly owned licensing subsidiary of the Dutch chemicals producer, Dutch States Mines (DSM). Stamicarbon licenses proprietary processes and expertise, developed and commercially proven by its mother company.

The chemical group DSM NV is a private corporation with its main offices in Geleen in The Netherlands. DSM is active on a global basis in several areas of the chemical process industry and has about 22,700 employees worldwide.

Introduction

Stamicarbon has long-standing experience in urea technology. The first license contract for a commercial urea plant dates back to 1954. Therefore, at this time the company has more than 45 years of urea experience.

During these 45 years, Stamicarbon technology has been licensed for over 200 urea units ranging from 70 to 3,000 mtpd, with a total production capacity of about 50 million mtpy. This equals about 45% of today’s world urea production capacity.

The first plant was based on the conventional process developed by DSM. A thorough understanding of the ammonia—carbon dioxide—urea—water thermodynamical phase system was gained from extensive fundamental research. These efforts led to the invention of the revolutionary Stamicarbon CO₂ stripping process, which was developed in the early 1960s and first licensed in 1965.

By continuous optimization with respect to energy, feedstock consumption, and investment, the CO₂ stripping process has retained its attractiveness throughout the years and is still a leading process. With the introduction of the pool condenser and pool reactor in the late 1990s, a revolutionary step in the technology was again taken by Stamicarbon.

This paper reviews the impact of a world-scale Stamicarbon-designed urea plant on the environment.

Impact of a World-Scale Urea Plant on the Environment

In 1993 Stamicarbon successfully commissioned two world-scale urea production plants giving special attention to the environment. These plants are the single-line urea plant (presently, 3,000 mtpd) of Saskferco in Belle Plaine, Saskatchewan, Canada, and the 1,800-mtpd single-line urea plant of Safco in Al-Jubail, Saudi Arabia. A 1,750-mtpd single-line urea plant incorporating Stamicarbon’s novel Poolcondenser concept (part of our Urea 2000plus™ technology) was started in 1994 for Kafco in Bangladesh.

Another 2,000-mtpd single-line urea plant for Qafco in the city of Umm Said in Qatar was commissioned in 1997, and plants were commissioned in 1998 at DSM in The Netherlands and CF Industries in the United States. For all these plants very stringent environmental requirements had to be fulfilled.

Stamicarbon’s achievements in reducing the effluents and emissions from a urea plant during operation over the last 15 years have been remarkable. In the early part of the previous decade, ammonia consumption per metric ton of final product of 575 kg or even higher was acceptable. This figure implies, however, a loss of some 8 kg/mt of final product produced (Table 1), which for a 2,000-mtpd plant would result in a loss of 16 mtpd...
Table 1. Ammonia Releases From Urea Plants

| Early 1980s | 8 kg NH₃/mt final product |
| Presently (1997) | 0.7 kg NH₃/mt final product |

ammonia either in the form of urea or straight ammonia.

Presently, ammonia consumption of 567 kg/mt has been achieved in the large single-stream plants. In that this figure is very close to the theoretical consumption figure, the conclusion is that losses during steady operation are approaching the zero target.

Not only do ammonia, carbon dioxide, and urea releases from process plants have a negative influence on the environment but also the unnecessary use of energy has a negative effect from an environmental point of view and from the economic point of view as well. The CO₂ stripping urea process of Stamicarbon has had from the early days onward the feature of both high CO₂ and NH₃ conversion. Since NH₃ and CO₂ conversions in the synthesis section of a Stamicarbon CO₂ stripping urea plant are high, the need for recycle of unconverted NH₃ and CO₂ is reduced. The CO₂ conversion in the synthesis section is typically 80%-81% while the ammonia conversion in the synthesis section is typically as high as 82%.

Consequently, a single-stage recirculation step at low pressure and with a minimal size is sufficient for a Stamicarbon plant with total NH₃ and CO₂ recycle, thus considerably reducing the consumption of electricity, steam, and cooling water.

Figures for typical energy consumption at present are shown in Table 2.

Today, plants are equipped with the following features to keep the effluents and emissions at extremely low levels:

- Nitrogen to carbon (N/C) ratio meter.
- Wastewater treatment section.
- Absorbers.
- Special operational facilities.

N/C Ratio Meter in the Synthesis Section

Instead of a gas chromatograph or a mass spectrometer in the gas phase of the synthesis section, Stamicarbon developed proprietary technology and presently uses this in a so-called nitrogen/carbon ratio meter installed in the liquid phase (reactor liquid outlet) of the urea synthesis section (see Figure 1).

The principle of this N/C meter is based on the linear relationship between liquid density and the N/C ratio. The density is measured continuously with a solartron meter, an instrument that measures vibrations in an extremely accurate way, and the vibrations are related to the density of the reactor liquid.

This N/C ratio meter allows the process to be operated at all times at the optimum ratio to achieve the highest reactor efficiency combined with higher energy efficiency. Special procedures are used to eliminate emissions during startup.

Urea Plant Wastewater Treatment Section

The process water in urea plants contains ammonia, carbon dioxide, and urea. The concentrations of these components vary within a range depending on the operating

Table 2. Typical Consumption Figures for a Urea Granulation Plant

| Steam (22 bar, 330°C) | 805 kg/mt urea |
| Steam (4 bar saturated) (produced) | -415 kg/mt urea |
| Electricity (including granulation section) | 50 kWh/mt urea |
| Cooling water (including granulation section) | 58 mt/mt urea |

Figure 1. Flowsheet Location N/C Ratio Meter.
conditions and type of plant, e.g., crystallization or single- or two-stage evaporation. On average, the concentrations in the process water by weight are about 6% ammonia, 4% carbon dioxide, and 1% urea.

The principal sources of the ammonia and urea are the following:

- Condensate from the evaporators.
- Off-gases from the recirculation section, which are absorbed in the process water.
- Off-gases from the synthesis section, which are absorbed in the process water.
- Flush and purge water for pumps.
- Liquid drains.

The purpose of the process water treatment is to remove ammonia, carbon dioxide, and urea from the process condensate. The recovered ammonia and carbon dioxide are returned to the process to be subsequently converted into urea. The treated process condensate can be used for a variety of purposes such as cooling water or boiler feedwater makeup, depending on the quality required.

A short process description of this wastewater treatment process follows.

As shown in Figure 2, process water enters the first desorber (A), where the bulk of ammonia and carbon dioxide is removed. The urea-containing effluent from the first desorber is sent to the hydrolyzer (C) countercurrently, with 20 bar steam fed to the bottom, and the urea decomposes into ammonia and carbon dioxide at elevated temperature. Process conditions in this countercurrent hydrolyzer are mild, so normal stainless steel grades are applied. The ammonia and carbon dioxide evolving from this hydrolysis reaction are removed in a second desorber (B) using low-pressure (LP) steam as stripping agent. On leaving the process water treatment system, the effluent can be used as boiler feedwater or cooling water makeup. The overhead vapors of the second desorber and of the hydrolyzer are used as stripping agent in the first desorber.

The overhead vapors of the first desorber are condensed as a carbonate solution in a submerged-type reflux condenser (D). The water content of the carbamate solution is controlled by using carbamate solution as reflux in the first desorber. The remaining carbamate solution is sent to the recirculation section, and the noncondensed vapors are sent to the atmosphere after being treated in an atmospheric absorber.

As a result, the pressure in the process water treatment system is independent of the urea process pressure. Consequently, the process water treatment system is separated from the urea plant itself and can be applied in a urea plant of any design without disturbing the process sections. The wastewater treatment section can be added to a urea plant as a stand-alone unit. Process-to-process heat exchangers are applied for economy of energy.

Typical effluent values of the Stamicarbon wastewater treatment section are given in Table 3.

Many Stamicarbon wastewater treatment systems using the process described here are in operation and are giving excellent performance with ammonia and urea concentrations of less than 1 ppm. Some typical performance figures are given in Table 4.

A reference list of plants using countercurrent hydrolyzer systems is attached to this paper (Annex I).

**Absorbers**

The urea plant emissions to the atmosphere can be classified as follows:

a. **The vent from the synthesis section of the plant.**

The purge from the urea synthesis section contains inerts.

**Table 3. Typical Effluent Values**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Value (wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>1 ppm</td>
</tr>
<tr>
<td>Urea</td>
<td>1 ppm</td>
</tr>
</tbody>
</table>

Figure 2. Process Water Treatment System.
ammonia, and carbon dioxide. To avoid ammonia emissions from this purge, a low-pressure absorber is installed in this purge stream (Figure 3). First the ammonia is washed out with a large flow of cooled process water of low concentration, and then the remaining ammonia is absorbed in cooled condensate or clean wastewater. The remaining ammonia in this inert purge is thus reduced to about 2 kg/h.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Guaranteed Effluent Values</th>
<th>Measured Effluent Values</th>
<th>Utilization of Process Effluent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urea (ppm)</td>
<td>Ammonia (ppm)</td>
<td>Urea (ppm)</td>
</tr>
<tr>
<td>1.</td>
<td>5</td>
<td>5</td>
<td>&lt;5</td>
</tr>
<tr>
<td>2.</td>
<td>5</td>
<td>5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>3.</td>
<td>5</td>
<td>5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>4.</td>
<td>5</td>
<td>5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>5.</td>
<td>2</td>
<td>5</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

Figure 3. Low-Pressure Absorber.

b. The vent from the low-pressure section of the plant.

The ammonia and carbon dioxide present in the off-gases of the recirculation section, the process water treatment system, and the evaporation section are washed out in an atmospheric absorber (Figure 4), where large amounts of cooled process water with low concentrations of ammonia and carbon dioxide are used to absorb all the ammonia present in the off-gases. The remaining ammonia in this vent is reduced to some 2 kg/h as well.

c. The vent from the granulation section.

Although the technology for granulation is owned by another licensor, the environmental picture would not be complete if this part of the urea production facility were to be ignored in this paper.

The off-gases from this section contain ammonia and urea dust. The ammonia is in principle the free ammonia present in the highly concentrated urea solution fed to the granulator. This free ammonia is about 500 ppm, which for a 2,000-mtpd plant amounts to about 42 kg/h.

According to information from the granulator licensor, the urea dust emissions after scrubbing of the air stream from the fluid-bed granulator and cooling air stream are 15 kg/h for a 2,000-mtpd urea granulator, of which about 75% originates from the fluidization air scrubber and the remainder from the cooling air scrubber.

Special Startup, Shutdown, and Draining Facilities

Because of the present low releases during steady-state operation, the emphasis regarding environmental issues has shifted toward a further reduction of effluents and emissions from non-continuous sources during non-steady-state conditions such as startup and shutdown situations. Significant progress in this respect has been made.

A change in the startup procedure of the urea synthesis section has reduced the impact on the environment considerably. Presently the ability to measure the feed flows (NH₃ and CO₂) very
accurately and also to measure the N/C ratio has made it possible to use the correct NH₃/CO₂ ratio in feeding the synthesis section from the very beginning of the startup, thus eliminating the need, during the initial stage of startup, to vent excess CO₂ accompanied by some NH₃ into the atmosphere. The large blow-off valve formerly installed on the urea reactor outlet line has been eliminated altogether.

Special shutdown and draining facilities ensure that nonconverted NH₃ and CO₂ are recovered by the process after a shutdown. To achieve this, a facility to feed clean water to dilute the carbamate formed from nonconverted NH₃ and CO₂ from the synthesis section has been introduced. The carbamate should be diluted to the extent that no ammonia will escape from the liquid under atmospheric pressure (storage condition).

The water is, in principle, introduced in the low-pressure carbamate condenser; subsequently, it is cooled to increase absorption capacity and drained into the ammonia water tank. After restart of the plant, the NH₃ and CO₂ in this tank are recovered via the wastewater treatment section. The clean water used for the dilution may be an amount of clean wastewater stored for such purpose. No additional storage of clean wastewater in the complex is required if sufficient condensate is available.

### Conclusions

Stamicarbon has in recent years further reduced the environmental impact of its CO₂ stripping urea process and presently incorporates the systems required to achieve low emissions in its standard new plant design. Furthermore, design measures related to startup, shutdown, restart, and upset plant conditions are included to avoid significant emissions during these conditions.

The high-efficiency counter-current hydrolyzer system has been licensed on a worldwide basis 36 times, as seen in Annex I. Because the water produced in the urea plant is recycled to the utility section and reused, no harmful effluent is purged from a modern urea plant.

The environmental impact from such a plant, including the finishing section, which is fluid-bed granulation, is therefore limited to emissions that under normal operations would be as shown in Table 5.

According to these data, the NH₃ efficiency is 99.9%.

### Table 5. Emissions From a Modern Stamicarbon Urea Plant

<table>
<thead>
<tr>
<th>Component</th>
<th>Emission (kg NH₃/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Liquid</strong></td>
<td></td>
</tr>
<tr>
<td>Synthesis section</td>
<td>2</td>
</tr>
<tr>
<td>Recirculation section</td>
<td>2</td>
</tr>
<tr>
<td><strong>Gaseous</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Total emission</strong></td>
<td>55 kg NH₃/h</td>
</tr>
</tbody>
</table>

a. As urea dust.
## Annex I

**Stamicarbon CO₂ Stripping Plants With Countercurrent Hydrolyzer**

<table>
<thead>
<tr>
<th>Date of Order</th>
<th>Units</th>
<th>Client</th>
<th>Country</th>
<th>Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>1</td>
<td>CdF Chimie-APC, Toulouse</td>
<td>France</td>
<td>Heurtey, France</td>
</tr>
<tr>
<td>1980</td>
<td>1</td>
<td>Al Jubail Fertilizers, Al Jubail</td>
<td>Saudi Arabia</td>
<td>Pullman Kellogg, U.S.A.</td>
</tr>
<tr>
<td>1981</td>
<td>1</td>
<td>National Petrochemicals Comp., Marsa el-Brega</td>
<td>Libya</td>
<td>Uhe, Germany</td>
</tr>
<tr>
<td>1981</td>
<td>1</td>
<td>Petrochemical Industries Corp., Kyaw Zwa</td>
<td>Burma</td>
<td>Uhe, Germany</td>
</tr>
<tr>
<td>1981a</td>
<td>1</td>
<td>Chemokomplex, Petfhrdo</td>
<td>Hungary</td>
<td>Coppee, Belgium</td>
</tr>
<tr>
<td>1982</td>
<td>1</td>
<td>Pupuk Kalimantan Timur, Bontang</td>
<td>Indonesia</td>
<td>The MW Kellogg Corp., U.S.A.</td>
</tr>
<tr>
<td>1982</td>
<td>1</td>
<td>Asean Bintulu Fertilizer Sdn.Bhd., Bintulu</td>
<td>Malaysia</td>
<td>Uhe, Germany</td>
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<tr>
<td>1985</td>
<td>1</td>
<td>State Organization of Industrial Design and Construction, Salhuddin Bajji</td>
<td>Iraq</td>
<td>M.W. Kellogg Ltd., UK</td>
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<tr>
<td>1985</td>
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<td>Pupuk Kalimantan Timur, Bontang</td>
<td>Indonesia</td>
<td>Chiyoda, Japan</td>
</tr>
<tr>
<td>1985a</td>
<td>1</td>
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<td>China</td>
<td>Client</td>
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<tr>
<td>1989</td>
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<td>State Organization of Industrial Design and Construction, Salhuddin Bajji</td>
<td>Iraq</td>
<td>M.W. Kellogg Ltd., UK</td>
</tr>
<tr>
<td>1989a</td>
<td>1</td>
<td>Asean Bintulu Sdn.Bhd.</td>
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<td>Uhe, Germany</td>
</tr>
<tr>
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<td>1</td>
<td>Saskerco Products Inc., Belle Plain Saskatchewan</td>
<td>Canada</td>
<td>Uhe, Germany</td>
</tr>
<tr>
<td>1990</td>
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<td>Kurnaphuli Fertilizer Co. Ltd.</td>
<td>Bangladesh</td>
<td>Chiyoda, Japan</td>
</tr>
<tr>
<td>1990</td>
<td>1</td>
<td>Saudi Arabian Fertilizer Company</td>
<td>Saudi Arabia</td>
<td>Chiyoda, Japan</td>
</tr>
<tr>
<td>1991</td>
<td>1</td>
<td>Khorasan Petrochemical Company</td>
<td>Iran</td>
<td>M.W. Kellogg Ltd., UK</td>
</tr>
<tr>
<td>1991</td>
<td>1</td>
<td>CF Industries, Donaldsonville, LA</td>
<td>United States</td>
<td>The MW Kellogg Corp., U.S.A.</td>
</tr>
<tr>
<td>1991a</td>
<td>1</td>
<td>Khorasan Petrochemical Company (KPC), Bojnurd</td>
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<td>M.W. Kellogg Ltd., UK</td>
</tr>
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<td>Client</td>
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<td>1992a</td>
<td>1</td>
<td>Joint Stock Company ATogliattiazot® Togliatti</td>
<td>Russia</td>
<td>Urea Casale S.A., Switzerland</td>
</tr>
<tr>
<td>1994</td>
<td>1</td>
<td>Sinopec Urumqi, Xinjiang Province</td>
<td>China</td>
<td>Lanzhou Design Institute, China</td>
</tr>
<tr>
<td>1994</td>
<td>1</td>
<td>Qatar Fertiliser Company S.A.Q, Umm Said</td>
<td>Qatar</td>
<td>Uhe, Germany</td>
</tr>
<tr>
<td>1994a</td>
<td>1</td>
<td>Canadian Fertilizers Limited, Medicine Hat, Alberta</td>
<td>Canada</td>
<td>Client</td>
</tr>
<tr>
<td>1995</td>
<td>1</td>
<td>Fauji Fertilizer Company Ltd., Port Qasim</td>
<td>Pakistan</td>
<td>Chemoproyekt, Czech Republic</td>
</tr>
<tr>
<td>1995</td>
<td>1</td>
<td>Heilongjiang Chemical Industry Corp., Qiqihar</td>
<td>China</td>
<td>China Wuhuan Chemical Engineering Corp., China</td>
</tr>
<tr>
<td>1995</td>
<td>1</td>
<td>CF Industries, Donaldsonville, LA</td>
<td>United States</td>
<td>Larsen and Toubro, India</td>
</tr>
<tr>
<td>1995a</td>
<td>1</td>
<td>Qatar Fertiliser Company, Umm Said</td>
<td>Qatar</td>
<td>Uhe, Germany</td>
</tr>
<tr>
<td>1996</td>
<td>1</td>
<td>DSM, Geleen</td>
<td>The Netherlands</td>
<td>Uhe, Germany</td>
</tr>
<tr>
<td>1996</td>
<td>1750</td>
<td>Abu Qir, Alexandria</td>
<td>Egypt</td>
<td>Uhe, Germany</td>
</tr>
<tr>
<td>1996</td>
<td>1725</td>
<td>P.T. Pupuk Kalimantan, Bontang</td>
<td>Indonesia</td>
<td>Chiyoda, Japan</td>
</tr>
<tr>
<td>1997</td>
<td>1</td>
<td>Petrochemical Industries Kuwait Co., Shuaiba</td>
<td>Kuwait</td>
<td>-</td>
</tr>
<tr>
<td>1997</td>
<td>1</td>
<td>Saudi Arabian Fertilizer Company</td>
<td>Saudi Arabia</td>
<td>Tecnimont, Italy</td>
</tr>
<tr>
<td>1997</td>
<td>1</td>
<td>SPIC Fertilizers &amp; Chemicals Company Ltd., Dubai</td>
<td>United Arab Emirates</td>
<td>M.W. Kellogg Ltd., UK</td>
</tr>
<tr>
<td>1997</td>
<td>1050</td>
<td>CNCCC, Zepu Petroleum Chemical Plant, Xinjiang Petroleum Administration Bureau, Zepu, Xinjiang Province</td>
<td>China</td>
<td>Krebs, France</td>
</tr>
<tr>
<td>1998</td>
<td>1750</td>
<td>Egyptian Fertilizer Corporation</td>
<td>Egypt</td>
<td>Krupp Uhde, Germany</td>
</tr>
</tbody>
</table>

a. Separate contracts for wastewater treatment systems.
Introduction

History

Compound or complex fertilizers are multinutrient phosphate-containing fertilizers—NP/NPK with S, Mg, Ca, and other micro-nutrients. The expression “nitrophosphate” is conventionally used to describe any fertilizer produced by a process involving the treatment of phosphate rock with nitric acid (the nitro route). The major process for multinutrient phosphate fertilizers uses sulfuric acid for the treatment of phosphate rock (the sulfur route). Phosphoric acid is the intermediate product for both processes. Multinutrient fertilizers based on the sulfur route were introduced in 1927 by I.G. Farben-industrie (BASF). In 1928 a Norwegian, E. B. Johnson, introduced and patented a nitrophosphate process known as the “Odda” process, which later was licensed to BASF, Hoechst, DSM, and Norsk Hydro.

Norsk Hydro began its nitrophosphate production in 1935, and today the annual capacity in Norway at Glomfjord and Porsgrunn is 2.2 million mt NPK. Norsk Hydro has devoted much effort to research and development work on the nitrophosphate process technology. Although most of the main process elements of the original Odda process have been retained, the latest Norsk Hydro nitrophosphate process is used in advanced technology plants with high on-stream factor, high-energy efficiency, high-nutrient utilization, low-environmental effluents, and excellent product quality.

Norsk Hydro has licensed its nitrophosphate process to Romania, Hungary, Russia, and China. The total capacity based on Norsk Hydro’s nitrophosphate technology is approximately 10 million mtpy (Table 1). Most of the technology developed by the company to minimize effluents can also be applied to other compound fertilizer processes.

Technology of the Nitrophosphate Process

The nitrophosphate concept requires high integration between the different plants. Only nitrate-containing fertilizers can be produced via this route (Figure 1). The location of the nitrophosphate unit should for practical purposes be alongside an ammonia plant to have carbon dioxide available. In this manner CO₂ emission from that plant can be reduced. Of course, there is the possibility of supplying CO₂ from alternative plants. However, the nearby ammonia plant would be beneficial because liquid ammonia might be used for crystallization of cal-

<table>
<thead>
<tr>
<th>Country</th>
<th>Location</th>
<th>Startup</th>
<th>Capacity</th>
<th>P₂O₅ Capacity (mtpd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norway</td>
<td>Glomfjord</td>
<td>1955</td>
<td>2,000</td>
<td>220</td>
</tr>
<tr>
<td>Norway</td>
<td>Porsgrunn</td>
<td>1967</td>
<td>2,700</td>
<td>370</td>
</tr>
<tr>
<td>Norway</td>
<td>Porsgrunn</td>
<td>1987</td>
<td>4,000</td>
<td>400</td>
</tr>
<tr>
<td>Hungary</td>
<td>Petfurdo</td>
<td>1975</td>
<td>2,200</td>
<td>240</td>
</tr>
<tr>
<td>Romania</td>
<td>Tiru Mures</td>
<td>1975</td>
<td>2,700</td>
<td>300</td>
</tr>
<tr>
<td>Romania</td>
<td>Craiova</td>
<td>1976</td>
<td>2,700</td>
<td>300</td>
</tr>
<tr>
<td>Romania</td>
<td>Turnu Magurele</td>
<td>1976</td>
<td>2,700</td>
<td>300</td>
</tr>
<tr>
<td>Russia</td>
<td>Novgorod</td>
<td>1982</td>
<td>1.850</td>
<td>305</td>
</tr>
<tr>
<td>Russia</td>
<td>Novgorod</td>
<td>1983</td>
<td>1.850</td>
<td>305</td>
</tr>
<tr>
<td>Russia</td>
<td>Dorogobuzh</td>
<td>1984</td>
<td>1.850</td>
<td>305</td>
</tr>
<tr>
<td>Russia</td>
<td>Dorogobuzh</td>
<td>1984</td>
<td>1.850</td>
<td>305</td>
</tr>
<tr>
<td>Russia</td>
<td>Rossosh</td>
<td>1984</td>
<td>1.850</td>
<td>305</td>
</tr>
<tr>
<td>China</td>
<td>Lucheng Shanxi</td>
<td>1987</td>
<td>2.970</td>
<td>390</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>31,220</strong></td>
<td><strong>4,045</strong></td>
</tr>
</tbody>
</table>
Figure 1. Norsk Hydro’s Nitrophosphate Process—Integrated Process Scheme.

cium nitrate tetrahydrate (CNOTH), and the gaseous ammonia subsequently could be used for neutralization. Preferably, the nitric acid plant should also be an integral part of the nitrophosphate complex because the surplus steam produced can be used to evaporate water from solutions in other units. In total, the steam produced by the ammonia and nitric acid plants will more than supply the steam demand in a nitrophosphate/ammonium nitrate coproduction unit. An integrated double-extraction condensing turbine will also supply the necessary power demand (except for startup) with a small surplus.

Reference Plants
The following discussion on nitrophosphate technology and potential sources of pollution is based on data from one of the NPK plants at Hydro Agri in Porsgrunn. This plant is part of a primary fertilizer complex, producing a wide variety of NPK fertilizer products. The reference NPK plant is based on the prilling process and has the following characteristics:

<table>
<thead>
<tr>
<th>Capacity</th>
<th>mtpd</th>
</tr>
</thead>
<tbody>
<tr>
<td>P₂O₅</td>
<td>400</td>
</tr>
<tr>
<td>NPK 1-1-1 grade</td>
<td>2,700</td>
</tr>
<tr>
<td>PK 2-1-1 grade</td>
<td>4,000</td>
</tr>
</tbody>
</table>

The overall N:P₂O₅ ratio from the nitrophosphate process is 2:1, which means that when NPKs are produced with lower ratios, the excess nitrogen has to be processed into other products including the following:

- Ammonium nitrate/calcium ammonium nitrate fertilizer.
- Ammonium nitrate explosive grade/fertilizer grade.
- Calcium nitrate fertilizer.
- Urea ammonium nitrate solution.

The quantities for these byproducts per unit NPK will vary with the ratio of CaO to P₂O₅ in the phosphate rock and with the NPK production program, e.g., with the market demand (Table 2).

Table 2. Norsk Hydro’s Nitrophosphate Process (Products and Byproducts Quantities)

<table>
<thead>
<tr>
<th>Product</th>
<th>Quantity</th>
<th>Byproduct</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPK 16-16-16</td>
<td>100</td>
<td>CAN (26% N)</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CaCO₃ (surplus)</td>
<td>17</td>
</tr>
<tr>
<td>NPK 16-16-16</td>
<td>100</td>
<td>AN (34.5% N)</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CaCO₃</td>
<td>30</td>
</tr>
<tr>
<td>NPK 16.016-16</td>
<td>100</td>
<td>Calcium nitrate (15.5% N)</td>
<td>64</td>
</tr>
<tr>
<td>NPK 22-11-11</td>
<td>100</td>
<td>CAN/AN</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CaCO₃</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Calcium nitrate</td>
<td>0</td>
</tr>
</tbody>
</table>
The discussion on calcium ammonium nitrate technology is based on Hydro Agri’s 1,500-mtpd plant at Sluiskil, The Netherlands.

Discussions on production of explosive-grade ammonium nitrate are referred to a 450-mtpd plant in Koping, Sweden.

Finally, regarding calcium nitrate fertilizer production, the reference plant is again Hydro Agri, Porsgrunn, where a pan granulation plant with two 1,200-mtpd trains each is in operation.

In this paper, discussions of the nitrophosphate plant and the different byproduct alternatives will primarily deal with meeting the best available technology (BAT) for pollution prevention as described by the European Fertilizer Manufacturers’ Association (EFMA) in 1995. In general, the various aspects of production flexibility and environmental benefits for nitrophosphate versus phosphoric acid-based NPK production are illustrated in Tables 3-5.

Discussions of comparative economics on production of NPK via the nitrophosphate route and via the phosphoric acid route are included in the last section of the paper.

### The Nitrophosphate Production Process

#### Basic Principle

The phosphate source is converted into the available form by producing compound fertilizer containing ammonium nitrate, ammonium phosphate, and potassium salts (Figure 2). The first step is dissolution of phosphate rock in nitric acid:

\[
\text{Ca}_5\text{F} \left(\text{PO}_4\right)_3 + 10 \text{HNO}_3 \rightarrow 3 \text{H}_3\text{PO}_4 + 5\text{Ca} \left(\text{NO}_3\right)_2 + \text{HF}
\]

The solution, called “digestion liquor,” contains too many calcium ions, which limits the P₂O₅ readily available for the plants. Therefore, the solution is cooled so that CNTH crystallizes out:

### Table 3. NPK Production Flexibility

<table>
<thead>
<tr>
<th>Nitrophosphate</th>
<th>Phosphoric Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum N/P₂O₅ ratio in NPK is 0.8 (without the addition of extra P₂O₅).</td>
<td>MAP/DAP can be produced in the NPK plant.</td>
</tr>
<tr>
<td>The overall N/P₂O₅ ratio is 2:1, e.g., the “ideal” NP(K) is 22-11 (-11).</td>
<td>Good flexibility in NPK product grades (N/P₂O₅ ~ 0.2 – 1 (no N-containing byproduct).</td>
</tr>
<tr>
<td>NPK 1-1-1 without N-containing byproduct needs a supply of extra P₂O₅ (TSP, phosacid).</td>
<td>Flexible location.</td>
</tr>
<tr>
<td>Access to CO₂ necessary, e.g., ammonia and nitrophosphate plant on same site.</td>
<td></td>
</tr>
</tbody>
</table>

### Table 4. Nitrophosphate or Phosphoric Acid to NPK

<table>
<thead>
<tr>
<th>Nitrophosphate</th>
<th>Phosphoric Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>• NOₓ pollution</td>
<td>• No NOₓ</td>
</tr>
<tr>
<td>• No SO₂ pollution</td>
<td>• S is “wasted”</td>
</tr>
<tr>
<td>• CO₂ is consumed to produce CaCO₃</td>
<td>• 5 mt gypsum is produced per mt P₂O₅</td>
</tr>
<tr>
<td>• 2.5 mt CaCO₃ is produced per mt P₂O₅</td>
<td>• Gypsum may be utilized to produce:</td>
</tr>
<tr>
<td>• CaCO₃ can be utilized in:</td>
<td>➤ Plasterboard</td>
</tr>
<tr>
<td>➤ CAN fertilizer</td>
<td></td>
</tr>
<tr>
<td>➤ Soil conditioner</td>
<td></td>
</tr>
<tr>
<td>➤ Cement</td>
<td></td>
</tr>
<tr>
<td>➤ Blasting agent for cleaning of buildings</td>
<td></td>
</tr>
<tr>
<td>• NPK plus CN would give no byproduct</td>
<td></td>
</tr>
<tr>
<td>• CN can be utilized as:</td>
<td></td>
</tr>
<tr>
<td>➤ Fertilizer</td>
<td></td>
</tr>
<tr>
<td>➤ Additive in various industrial products</td>
<td></td>
</tr>
<tr>
<td>➤ Sewage treatment ingredient</td>
<td></td>
</tr>
</tbody>
</table>
Table 5. Norsk Hydro’s Nitrophosphate Process (Application of Calcium Nitrate Byproduct)

- As nitrate fertilizer with soluble calcium.
- In sewage and septic systems for odor control.
- In industrial wastewater to remove sulfides.
- In animal manure to remove smell before spreading.
- For revitalization of lakes (to avoid anaerobic conditions).
- In industrial liquid explosives to increase stability and nitrate content.
- For coagulation of natural rubber latex.
- For treatment of nuclear waste.
- In concrete to accelerate the setting and to improve long-term strength.
- In drilling mud “as heavy liquid.”
- In production of refractory bricks.
- In recycling of plastic (HDPE and PET) for speeding up flotation.

Figure 2. Norsk Hydro’s Nitrophosphate Process—Principal Process Steps.

\[ H_3PO_4 + HNO_3 + Ca\ (NO_3)_2 + 4H_2O \rightarrow H_3PO_4 + HNO_3 + Ca\ (NO_3)_2 + 4H_2O \]

The solution of phosphoric and nitric acid, called “mother liquor,” is separated from the CNTH crystals by filtration. The “mother liquor” is neutralized with ammonia and extra ammonium nitrate is added if needed depending on the NPK grade. Then potassium/magnesium salts and micronutrients are mixed in and converted in a pug-mill or prilling operation to solid compound fertilizer.

The separated calcium nitrate crystals can be processed via melting, evaporation, and pan granulation into solid CN fertilizer containing 15.5% N. Alternatively, the CNTH crystals are dissolved in ammonium nitrate solution and reacted with ammonia and carbon dioxide as follows:
Ca(NO₃)₂ + 2NH₃ + CO₂ + H₂O → CaCO₃ + 2NH₄NO₃

The solution is filtered, and the calcium carbonate crystals can be used to make calcium ammonium nitrate or used in different ways as a separate product. The ammonium nitrate solution is concentrated and returned to either the nitrophosphate section or further processed into ammonium nitrate fertilizer or explosive-grade ammonium nitrate.

**The Environmental Implications**

**Wet Section**

The first step is to dissolve phosphate rock in 60%-62% nitric acid. The reaction is exothermic with a very high reaction rate compared to the use of sulfuric acid. However, the temperature does not normally rise above 700°C because cold “wash acid” from CNTH filtration is recycled to this step (Figure 3).

The emission of NOₓ, resulting from the presence of reducing agents, can be efficiently suppressed by the addition of small amounts of urea. The quantity will depend upon the type of rock and 1-9 kg of urea per metric ton P₂O₅ that is needed to reduce the NOₓ to about 3 kg NO₂/metric ton P₂O₅.

Release of fluorine, especially in the form of SiF₄, might be significant depending on the fluorine content of the rock being used. However, both NOₓ and HF/SiF₄ can be efficiently scrubbed out as long as precipitation of gel such as SiO₂ is avoided. The solution from the scrubber is sent to the NP-liquor concentration plant.

A more serious problem may be created by acid insoluble solids in the rock. The percent of this quartz sand may vary from very little to as much as 10%-12% in the worst case. The sand, even at an average particle size of less than 10 mm, will cause serious erosion on rotating equipment (pumps) and in valves and pipes. Because of the small particle size, centrifuging is the only efficient method for separating the particles. Norsk Hydro has successfully developed a centrifuge that withstands the erosion, which normally occurs during the separation process.

The vent air from the subsequent process steps—crystallization and filtration of CNTH—also contains some NOₓ and NO₃⁻ and small amounts of fluorine. This air can be treated in a packed scrubber with the addition of small quantities of urea. When these scrubbing devices are operating properly, it is possible to control the atmospheric emissions from this section to less than 0.7 kg NO₂/metric ton P₂O₅ and 0.05 kg NO₃⁻N/metric ton P₂O₅. The fluorine level would normally be less than 0.02 kg/metric ton P₂O₅. The solution from these scrubbers is
sent to the NP-liquor concentration section.

**Calcium Nitrate Tetrahydrate Conversion**

Norsk Hydro has developed its own version of this process step where ammonium carbonate is produced in a circulating solution of ammonium nitrate. Carbon dioxide from the ammonia plant and gaseous ammonia from the refrigeration section are the raw materials:

$$2 \text{NH}_3 + \text{CO}_2 + \text{H}_2\text{O} \rightarrow (\text{NH}_4)_2 \text{CO}_3$$

The ammonium carbonate is then reacted with calcium nitrate:

$$\text{Ca(NO}_3)_2 + (\text{NH}_4)_2 \text{CO}_3 \rightarrow \text{CaCO}_3 + 2\text{NH}_4\text{NO}_3$$

The CaCO$_3$ is filtered off and sent to storage/battery limits. There is no continuous liquid effluent from this section, and the off-gases are treated together with other ammonia-containing vent gases in a scrubber using nitric acid.

The ammonium nitrate solution from the filtration step is treated in a second filter stage, a "polishing filter," to remove remaining CaCO$_3$ crystals. Any excess ammonium carbonate is neutralized with nitric acid and the clean, slightly alkaline, ammonium nitrate solution is eventually pumped to an evaporation section. The concentration is increased from 60% to 95% through a series of falling film evaporators, either double effect or triple effect depending on local energy costs.

The 95% solution can be returned to the NPK-process to adjust to the correct N:P$_2$O$_5$ ratio and can also be the basis for CAN production and/or AN fertilizer and explosive-grade AN. The vapor from the evaporation section, which contains small amounts of entrained liquor and ammonia, is treated in a scrubber. The ammonium nitrate solution used in the scrubbers is sent to the conversion plant while the scrubbed vapor is condensed. The condensate is sent to a common ammonia stripper.

**Neutralization**

After filtration of the CNTH, the "mother liquor" goes to three main process steps to produce the final compound fertilizer: (1) neutralization, (2) particle formation, and (3) conditioning. In the Norsk Hydro nitrophosphate process the "mother liquor" is neutralized with gaseous ammonia in a self-circulating (no circulating pump) reactor operating at 1.5–2.5 bar and 150°–175°C. The process vapor from the neutralizer contains about 2%-8% of ammonia. The vapor is scrubbed by small amounts of water to collect any carryover, and this water is returned to the process. After indirect condensation, the condensate is passed to the common ammonia stripper previously mentioned.

The neutralized solution is fed to the evaporation step, which may be one stage for pug mill granulation or two stages for prilling of NPK. The vapor from these stages contains ammonia (2%-7%) and a small amount of fluorine. Ammonium nitrate solution is used in packed scrubbers to absorb fluorine and remove any carryover from the evaporators. The ammonium nitrate solution is returned to the conversion section where fluorine is precipitated and the scrubbed vapor goes to indirect condensation and is then sent to the common ammonia stripper. Any uncondensed ammonia and inert gas from the neutralization and evaporation section are washed in a scrubber with the feed nitric acid.

Ammonia recovered from the stripper is returned to process and the treated condensate is sent to battery limits. The ammonia content of the stripped condensate can be as low as 10 ppm, if required, through the addition of a strong alkaline component like sodium hydroxide.

It is possible to reduce the effluent to the atmosphere from the neutralization/evaporation sections to:

- NH$_3$-N: 15 mg/Nml and 0.03 kg/mt P$_2$O$_5$
- NO$_3$-N and F: Negligible

**Prilling**

The NP liquor, which is almost free of water, flows by gravity from the final evaporator into the mixer where the required salts and recycled product are added (Figure 4). The mixer overflows into a rotating prill bucket from which the slurry is sprayed into the prill tower. Fans at the top of the tower induce ambient air which flows countercurrent to the slurry droplets. The solid prills fall onto a rotating-tower bottom and are scraped off to enter the dry handling system.

The dust emissions from the prilling tower are very low when producing nitrophosphate NPK compared to straight fertilizers like urea or ammonium nitrate. Thus, no air treatment systems are needed for the large amount of cooling air because dust concentration is less than 5 mg/Nm$^3$. This means that the total dust emission is less than 5 kg/h for a 4,000-mtpd NPK plant.

The NPK melt leaves the prill bucket at relatively high temperatures, which results in release of ammonia gas into the prilling tower. The amount of NH$_3$ released is related to several process parameters. Among the most important are mixing/prilling temperature, P$_2$O$_5$/concentration, and mole ratio NH$_3$/P$_2$O$_5$ (pH).

As described above, the prilling tower has no recovery system for the air leaving the tower. Thus, the escaping NH$_3$ gas will
enter into the atmosphere, representing nitrogen loss from the plant. However, the NH₃ concentration is low due to the more than 1 million M³/h of air passing through the prill tower. Normal concentrations are 10-15 mg NH₃/NM³.

**Dry Section (Salt Preparation and Dry Handling Systems)**

The function of the salt preparation system is to provide dried and screened potassium and other mineral salts to the NPK mixer. Vent air from the drying, screening, and transportation system is collected in a bag filter, and normally less than 0.5 kg/h escapes to atmosphere.

In the dry handling part of the NPK plant, the product leaving the prilling tower is screened to meet product specifications. Oversize and undersize material is recycled to the process. After screening, the NPK product is cooled in fluid-bed coolers before being sent to storage. For new plants, however, bulk flow coolers are recommended based on the successful experience in Norsk Hydro’s own Porsgrunn plant. In the final step, coating agents are added.

All of the equipment in the dry handling section, except for fluid bed coolers, is connected to one bag filter. If properly designed, one bag filter installation reduces losses to the atmosphere to less than 0.5 kg dust/h. Cooling air from the fluid-bed coolers is treated by a set of high efficiency cyclones. Normally more than 150,000 Nm³/h of cooling air is treated, and less than 1 kg dust/h enters the atmosphere at a concentration of approximately 5 mg dust/Nm³. Summarizing, the total dust effluent from salt preparation and dry handling sections is less than 2 kg dust/h, and this quantity can be further reduced by using a bulk flow cooler. There is no loss of water from these sections.

**Pug Mill Granulation**

The NP liquor with 2.5%-5% water and at 150°-170°C flows into the pug mill with required salts and recycle material (Figure 5). The granules from the pug mill are subsequently dried in a rotary dryer with hot air to a water content of 0.5%. Oversized granules, after crushing, and undersized granules are returned to the pug mill. Dust collected from screening, crushers, and conveyor discharge points and dust-laden air from the dryer is removed by cyclones and finally a bag filter. The fluid-bed coolers, which are equipped with cyclones to remove dust from the
Granulation route

Figure 5. Norsk Hydro’s Nitrophosphate Process—Treatment of Gaseous Effluents From Dry Section, Granulation Route.

air, can be replaced by bulk flow coolers and thus reduce dust emissions to the atmosphere. With fluid-bed cooling the atmospheric emissions would be:

- 0.6-0.9 kg particulates/mt P₂O₅
- 0.3 kg NH₃/mt P₂O₅

Wastewater Treatment System

Norsk Hydro’s wastewater treatment system, which began operation in 1977, is designed to produce water suitable for reuse within the NPK plant, thereby eliminating discharge of nutrient-polluted discontinuous waste from the plant (Figure 6). The system is designed to treat polluted wastewater from discontinuous operations such as leakage from process equipment and general cleaning. The wastewater is collected and treated before being reused. The solid contaminants are separated from the wastewater and recirculated with any excess water to the NPK process.

For safety reasons and to avoid corrosion of the equipment both in the NPK plant and the wastewater system, it is necessary to keep strict control of the chlorine content of any purified water recirculated to the evaporation section of the NPK process. For this reason, the collection and recirculation of wastewater is divided into two separate systems, namely:

- Chlorine water system.
- Phosphoric water system (P-water system).

Main sources for chlorine-containing water are NPK dry handling and mixing/prilling areas, while the wet section of the plant and the NPK evaporation section are sources of the P-water in the system. By separation into two systems and continuous automatic analyses of chlorine content in the purified water, it is possible to control the chlorine content at a safe and acceptable level.

Precipitation of contaminants in the wastewater takes place in the P-water surge tank by adjusting pH with NH₃ and calcium carbonate from the conversion section of the plant. Subsequent separation of the precipitates takes place in the sedimentation tank after addition of a flocculating agent followed by a centrifuge. The overflow from the sedimentation tank is acidified by nitric acid before being used for cleaning purposes in the plant. The liquid phase discharge from the centrifuge is returned to the wastewater treatment system, while the separated solids are returned to the digestion section of the plant.

The Byproduct Production Processes

Calcium Nitrate Fertilizer

The calcium nitrate crystals from the nitrophosphate process can be converted to solid fertil-
Ammonia Flocculating agent

Calcium carbonate

Cl⁻-containing effluent

P₂O₅-containing effluent

Cl⁻-water sump

P-water sump

Neutralization

Sedimentation

Centrifuge separation

Purified water for washing

Sludge to digestion

Figure 6. Norsk Hydro’s Nitrophosphate Process—Discontinuous Effluent Water Treatment System.

izer using prilling or pan granulation technology (Figure 7). The crystals are melted and neutralized with gaseous ammonia in a two-stage atmospheric tank system. A scrubber collects any NH₄-N and NO₃-N from neutralization, and the atmospheric emission is less than 0.003 kg N/mt CN.

In the evaporation section (one or two stages), the CN concentration is increased from 60% to 85%, and the concentrated solution is pumped to a pan-granulation unit. The ammonia-containing vapor from evaporation is scrubbed by clean process condensate to remove any entrained solution and can be used in the evaporators, thereby recovering energy. For a new plant, the condensate would finally be sent to a common ammonia-stripping unit.

The concentrated melt is sprayed onto the bed of particles in the pan granulator where fines are also introduced. The granules are cooled in a fluid bed cooler, screened, and on-size product goes to a coating drum. Oversize material is crushed, mixed with fines, and recycled to the granulator.

The ventilation gases are scrubbed with process condensate from the other scrubbers in a lamella separator before being discharged to the atmosphere with other cleaned air streams. The condensate from the lamella separator, containing dissolved calcium nitrate, is mixed with any spillage collected from the dry part of the process and returned to the evaporation section.

Measured overall emissions to the atmosphere are:
0.01 kg N/mt CN or < 2 mg N/Nm³
0.04 kg particulates/mt CN or < 10 mg/Nm³

The nitrogen content of the liquid effluent could be reduced to as low as 0.03 kg N/mt CN fertilizer.

Production of AN Fertilizer/Explosive-Grade AN

An interesting combination with the nitrophosphate NPK would be a plant to produce, alternatively if need be, ammonium nitrate fertilizer and explosive-grade ammonium nitrate (Figure 8). The basic idea would be to operate the plant on explosive-grade AN but to build in necessary extra capacity in the evaporation and prilling section to also allow the production of fertilizer grade.

Ninety-five percent ammonium nitrate solution from the NPK plant is the starting material to which a suitable crystal modifier is added. Any off-specification product, such as ammonium nitrate solution, is also returned to the 95% solution tank. The solution is evaporated to a water content of 4%-5% for explosive
Figure 7. Norsk Hydro’s Pan Granulation Process for Calcium Nitrate Fertilizer.

Figure 8. Norsk Hydro’s Process for AN-Explosive - AN-Fertilizer Grade.
grade or 0.5% for fertilizer grade, and the melt is sent to prilling.

Ammonia and droplets of ammonium nitrate will be included in the vapor from evaporation. Good experience has been obtained by using fiber pad separators with spraying of nitric acid to first recover the ammonia as ammonium nitrate, which is then recovered by the fiber and filter. The cleaned vapor is indirectly condensed and used as process water for different purposes within the process section.

Prilling is performed in a specially designed, vibrating device that produces prills of very narrow size distribution. The device also makes it possible to use towers with much smaller diameter than towers using a spinning bucket, and the air flow is thus substantially reduced.

The problem of atmospheric pollution from AN prill towers, especially the ammonium nitrate fume, is well known. In Norsk Hydro's explosive-grade AN plant in Sweden, part of the air (via a shroud installation) is successfully treated by using nitric acid in combination with an irrigated fiber filter. For a new plant, the same technology would be applied, but the entire air stream would be treated and emissions values of less than 15 mg particulates/Nm³ can be achieved. The ammonia concentration can also be easily controlled at less than 10 mg/Nm³. The ammonium nitrate solution from the fiber filter is returned to the dissolution tank for off-specification material as described below.

When producing explosive-grade AN, the prills from the prill tower bottom pass to a drum dryer where removal of the water creates the porous structure of the particle. Due to the narrow particle size distribution of the prills, the small amount of off-specification material from screening is dissolved to produce a weak AN solution. The product is cooled in a fluid-bed cooler, and a conditioner is added in the final step.

Air from dust collection at various points in the system and the air from the fluid bed cooler are treated in a wet scrubber using the weak AN solution from the off-specification dissolution tank plus process condensate. The 60% solution from the scrubber is returned to the 95% solution tank. Atmospheric losses from the wet scrubber are negligible. There is no continuous liquid effluent from the process.

**Granular CAN/AN Fluid-Bed Process**

The 95% AN solution from nitrophosphate is mixed with CaCO₃ with recycle solution from wet scrubbers and with magnesium nitrate solution in an evaporator feed tank (Figure 9). Evaporation takes place by cir-

![Figure 9. Norsk Hydro's Fluid Bed Granulation Process for AN/CAN Fertilizer.](image-url)
cycling the slurry through a submerged heater and then passing it to a flash chamber.

The slurry is then pumped to the fluid-bed unit through the spray nozzles whereby it is injected into the fluidized layer. Atomizing air heated up to above the melting point of the feed is used to improve injection. Fluidization air is provided by a large blower, and air to the granulation chamber is preheated by means of low-pressure steam or condensate.

The solids loop consists of an elevator, screens, a crusher, and fluid-bed cooler. The product may be coated depending on the mode of transportation used to move the fertilizer to the market.

Air exhausted from the granulator is treated in a two-stage scrubber. The first stage is designed to remove most of the calcium carbonate that may otherwise settle in the second stage and plug the final demister pad. Air exhausted from the coolers contains minor concentrations of dust, which is removed in a low-pressure drop scrubber. The washing solution recirculates to the granulator scrubber at about 50% concentration.

Wet scrubbing has been proved to be particularly well suited for obtaining compliance with the BAT standards for atmospheric emissions, e.g., 30 mg/Nm$^3$ of particulate and 20 mg/Nm$^3$ of ammonia.

**Summary**

Through many years of operation in Norway and from the diversified experience to meet strict pollution regulations also in other countries, Norsk Hydro’s nitrophosphate process can comply with required emission levels for existing plants. In addition, the company already has the experience to comply with emission levels for new plants as recommended by EFMA (Table 6). Because the overall N/P$_2$O$_5$ ratio of the nitrophosphate is 2:1, the process normally yields a nitrogen-containing byproduct, be it calcium ammonium nitrate, ammonium nitrate, or calcium nitrate. For all these byproducts, Norsk Hydro also has process experience to design plants to meet the required emission levels for new plants as recommended by EFMA. (Table 7).

### Comparative Economics for Production of NPK: Nitrophosphate Route Versus Phosphoric Acid Route

**Investment Estimates**

Investment estimates are shown in Table 8 for the following three types of process plants:

- Production of NPKs by the wet-process phosphoric acid route.
- Production of NPKs and CAN using the nitrophosphate process.
- Production of NPKs and AN using the nitrophosphate process.

**Assumptions for the Investment Estimates**

European conditions have been assumed for developing the investment estimates. The basic plants have capacities of 1 million mt/py of NPK, plus the additional capacities for the AN and CAN plants. In the case of a nitrophosphate-based facility, it has been assumed that the location would be near an ammonia plant. Therefore, the investment required for an ammonia plant has not been included in the estimates. Further, the estimates do not include interest during construction and working capital. Estimates of the utilities and auxiliary facilities such as electrical, steam, interconnections, storage of raw materials and products, harbor, site preparation, buildings, project management, startup and commissioning expenses are heavily dependent on the actual plant site and company background/experience.

The figures shown in Table 8 are budget-type estimates as related to estimated costs of the

---

Table 6. Norsk Hydro Nitrophosphate Process Emissions to air and water (Basis: Production of NPK 16-16-16)

<table>
<thead>
<tr>
<th>BAT</th>
<th>Gaseous</th>
<th>Liquid</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mg/Nm$^3$</td>
<td>g/Nm$^3$</td>
<td>kg/mt NPK</td>
</tr>
<tr>
<td>For New Plants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO$_x$ (as NO$_2$)</td>
<td>200</td>
<td>10</td>
<td>0.10</td>
</tr>
<tr>
<td>NH$_3$-N</td>
<td>15</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>NO$_3$-N</td>
<td>0</td>
<td>70</td>
<td>0.005</td>
</tr>
<tr>
<td>P$_2$O$_5$</td>
<td>5</td>
<td>5</td>
<td>0.003</td>
</tr>
<tr>
<td>F</td>
<td>5</td>
<td>100</td>
<td>0.05</td>
</tr>
<tr>
<td>Dust</td>
<td>50</td>
<td>4</td>
<td>0.4</td>
</tr>
</tbody>
</table>
### Table 7a. Norsk Hydro Nitrophosphate Process
#### Summary of BAT Emission Levels for New Plants Producing NPK and AN/CAN Granular

<table>
<thead>
<tr>
<th>NPK Plant</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission to air</td>
<td>NO\textsubscript{x} (as NO\textsubscript{2})</td>
<td>200 mg/Nm\textsuperscript{3}</td>
<td>0.12 kg/mt NPK</td>
</tr>
<tr>
<td></td>
<td>NH\textsubscript{3}-N</td>
<td>15 mg Nm\textsuperscript{3}</td>
<td>0.2 kg/mt NPK</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>5 mg Nm\textsuperscript{3}</td>
<td>0.00 kg/mt NPK</td>
</tr>
<tr>
<td></td>
<td>Dust</td>
<td>50 mg Nm\textsuperscript{3}</td>
<td>0.4 kg/mt NPK</td>
</tr>
<tr>
<td>Emission to water</td>
<td>P\textsubscript{2}O\textsubscript{5}</td>
<td>5 mg/L</td>
<td>0.003 kg/mt NPK</td>
</tr>
<tr>
<td></td>
<td>NH\textsubscript{3}-N</td>
<td>10 mg/L</td>
<td>0.007 kg/mt NPK</td>
</tr>
<tr>
<td></td>
<td>NO\textsubscript{3}-N</td>
<td>70 mg/L</td>
<td>0.03 kg/mt NPK</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>100 mg/L</td>
<td>0.05 kg/mt NPK</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AN/CAN Granulation Plant</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission to air</td>
<td>30 mg/Nm\textsuperscript{3} particulate</td>
<td>0.2 kg/mt AN/CAN</td>
<td></td>
</tr>
<tr>
<td></td>
<td>200 mg/Nm\textsuperscript{3} ammonia</td>
<td>0.1 kg/mt AN/CAN</td>
<td></td>
</tr>
<tr>
<td>Emission to water</td>
<td>No continuous effluent</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 7b. Norsk Hydro Nitrophosphate Process
#### Summary of BAT Emission Levels for New Plants Producing NPK and AN Prills

<table>
<thead>
<tr>
<th>NPK Plant</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission to air</td>
<td>NO\textsubscript{x} (as NO\textsubscript{2})</td>
<td>200 mg/Nm\textsuperscript{3}</td>
<td>0.12 kg/mt NPK</td>
</tr>
<tr>
<td></td>
<td>NH\textsubscript{3}-N</td>
<td>15 mg Nm\textsuperscript{3}</td>
<td>0.2 kg/mt NPK</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>5 mg Nm\textsuperscript{3}</td>
<td>0.00 kg/mt NPK</td>
</tr>
<tr>
<td></td>
<td>Dust</td>
<td>50 mg Nm\textsuperscript{3}</td>
<td>0.4 kg/mt NPK</td>
</tr>
<tr>
<td>Emission to water</td>
<td>P\textsubscript{2}O\textsubscript{5}</td>
<td>5 mg/L</td>
<td>0.003 kg/mt NPK</td>
</tr>
<tr>
<td></td>
<td>NH\textsubscript{3}-N</td>
<td>10 mg/L</td>
<td>0.007 kg/mt NPK</td>
</tr>
<tr>
<td></td>
<td>NO\textsubscript{3}-N</td>
<td>70 mg/L</td>
<td>0.03 kg/mt NPK</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>100 mg/L</td>
<td>0.05 kg/mt NPK</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AN Explosive/AN Fertilizer Prilling Plant</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission to air</td>
<td>Prill tower:</td>
<td>30 mg/Nm\textsuperscript{3} particulate</td>
<td>0.15 kg/mt AN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 mg/Nm\textsuperscript{3} ammonia</td>
<td>0.1 kg/mt AN</td>
</tr>
<tr>
<td></td>
<td>Cooler Drier:</td>
<td>30 mg/Nm\textsuperscript{3} particulate</td>
<td>0.1 kg/mt AN</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50 mg/Nm\textsuperscript{3} ammonia</td>
<td>0.12 kg/mt AN</td>
</tr>
<tr>
<td>Emission to water</td>
<td>No continuous effluent</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 7c. Norsk Hydro Nitrophosphate Process

**Summary of BAT Emission Levels for New Plants Producing NPK and CN Granular**

<table>
<thead>
<tr>
<th>NPK Plant</th>
<th>Emission to water</th>
<th>Emission to air</th>
<th>Emission to water</th>
<th>Emission to water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO(_x) (as NO(_2))</td>
<td>200 mg/Nm(^3)</td>
<td>0.007 kg/mt NPK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NO(_x) (as NO(_2))</td>
<td>200 mg/Nm(^3)</td>
<td>0.12 kg/mt NPK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NH(_3)-N</td>
<td>15 mg Nm(^3)</td>
<td>0.2 kg/mt NPK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>5 mg Nm(^3)</td>
<td>0.00 kg/mt NPK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dust</td>
<td>50 mg Nm(^3)</td>
<td>0.4 kg/mt NPK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P(_2)O(_5)</td>
<td>5 mg/L</td>
<td>0.003 kg/mt NPK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NH(_3)-N</td>
<td>10 mg/L</td>
<td>0.007 kg/mt NPK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NO(_3)-N</td>
<td>70 mg/L</td>
<td>0.03 kg/mt NPK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>100 mg/L</td>
<td>0.05 kg/mt NPK</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calcium Nitrate Pan Granulation Plant</th>
<th>Emission to air</th>
<th>0.035 kg/mt CN particulate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.0012 kg/mt CN ammonia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.03 kg/mt CN nitrogen</td>
</tr>
</tbody>
</table>

### Table 8. Estimated Investment Costs for Ammonium Phosphate-Based and Nitrophosphate-Based NPK Plants (Capacity: 1 million mtpy of NPK)

<table>
<thead>
<tr>
<th>NPK Plant Based On: Ammonium Nitrophosphate(^a)</th>
<th>Ammonium Phosphate</th>
<th>Nitrophosphate</th>
<th>CAN(^b)</th>
<th>AN(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- - - - - (million US $) - - - - -</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfuric acid, BL</td>
<td>26.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphoric acid, BL</td>
<td>44.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitric acid</td>
<td></td>
<td>60.7</td>
<td>60.7</td>
<td></td>
</tr>
<tr>
<td>NPK process plant</td>
<td>26.7</td>
<td>108.6</td>
<td>108.6</td>
<td></td>
</tr>
<tr>
<td>Calcium ammonium nitrate</td>
<td>8.7</td>
<td>14.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utilities</td>
<td>28.1</td>
<td>31.9</td>
<td>31.9</td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>51.4</td>
<td>54.8</td>
<td>52.8</td>
<td></td>
</tr>
<tr>
<td>Harbor and jetty</td>
<td>27.8</td>
<td>27.8</td>
<td>27.8</td>
<td></td>
</tr>
<tr>
<td>Site preparation</td>
<td>19.5</td>
<td>19.5</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td>Buildings, workshops, and roads</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td></td>
</tr>
<tr>
<td>Connections (internal and external)</td>
<td>16.2</td>
<td>17.8</td>
<td>17.8</td>
<td></td>
</tr>
<tr>
<td>Engineering and management</td>
<td>56.9</td>
<td>77.5</td>
<td>78.4</td>
<td></td>
</tr>
<tr>
<td>Pre-startup, commissioning, spares, freight, and insurance</td>
<td>20.9</td>
<td>28.5</td>
<td>29.1</td>
<td></td>
</tr>
<tr>
<td>Contingency</td>
<td>65.2</td>
<td>88.6</td>
<td>89.6</td>
<td></td>
</tr>
<tr>
<td><strong>Total Investment Estimate</strong></td>
<td><strong>390.2</strong></td>
<td><strong>531.4</strong></td>
<td><strong>537.6</strong></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) An ammonia plant to supply NH\(_3\) and CO\(_2\) not included.  
\(^b\) CAN capacity: 480,000 mtpy.  
\(^c\) AN capacity: 350,000 mtpy.
battery-limits process plants. These could vary considerably based on conditions at an actual plant site and could change the relative economics of the various processes.

**Economics of Production**

Estimates were made of the production costs for each of the three process alternatives. For purposes of the estimates, the following were assumed as plant production rates when producing a base-grade NPK of 16-16-16:

<table>
<thead>
<tr>
<th>Product</th>
<th>Production Rate (mtpy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPK (16-16-16)</td>
<td>1,000,000</td>
</tr>
<tr>
<td>CAN</td>
<td>480,000</td>
</tr>
<tr>
<td>AN (fertilizer or explosive grade)</td>
<td>350,000</td>
</tr>
</tbody>
</table>

Details of the production cost calculations are given in Tables 9, 10, and 11. Comparisons of the overall production cost and estimated income from sales are given below.

<table>
<thead>
<tr>
<th>Process</th>
<th>Total Production (mtpy)</th>
<th>Total Production Cost (US $)</th>
<th>Average Cost/mt of Product (US $)</th>
<th>Income From Sales (US $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPK only (phosphoric acid based)</td>
<td>1,000,000</td>
<td>170,777</td>
<td>170.77</td>
<td>180,000</td>
</tr>
<tr>
<td>NPK plus CAN (nitrophosphate based)</td>
<td>1,480,000</td>
<td>175,677</td>
<td>118.70</td>
<td>216,000</td>
</tr>
<tr>
<td>NPK plus AN (nitrophosphate based)</td>
<td>1,350,000</td>
<td>178,212</td>
<td>132.01</td>
<td>241,250</td>
</tr>
</tbody>
</table>

The estimated investments from Table 8 and the net incomes calculated from the data in Tables 9, 10, and 11 were used to calculate simple payback years of:

<table>
<thead>
<tr>
<th>Process</th>
<th>Payback Time (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPK only (phosphoric acid based)</td>
<td>45</td>
</tr>
<tr>
<td>NPK plus CAN (nitrophosphate based)</td>
<td>14</td>
</tr>
<tr>
<td>NPK plus AN (nitrophosphate based)</td>
<td>9</td>
</tr>
</tbody>
</table>

The average sales price of the three products were assumed as:

<table>
<thead>
<tr>
<th>Product</th>
<th>Sales Price (US $/mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPK (16-16-16)</td>
<td>180</td>
</tr>
<tr>
<td>CAN</td>
<td>75</td>
</tr>
<tr>
<td>AN (explosive grade)</td>
<td>175</td>
</tr>
</tbody>
</table>
### Table 9. NPK (16-16-16) Production Cost

<table>
<thead>
<tr>
<th></th>
<th>Cost (US $/mt)</th>
<th>Sales Price (mtpy)</th>
<th>Quantity (mt)</th>
<th>Cost (US $1,000/year)</th>
<th>Income (US $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPK (16-16-16)</td>
<td>171</td>
<td>180</td>
<td>1,000,000</td>
<td>170,777</td>
<td>180,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>171</td>
<td>180</td>
<td>1,000,000</td>
<td>170,777</td>
<td>180,000</td>
</tr>
</tbody>
</table>

#### Total Operating Costs

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Price (US $/mt)</th>
<th>Units/Year (mt)</th>
<th>Cost (US $/1,000 year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphate rock, ((32.5% \text{ P}_2\text{O}_5))</td>
<td>70</td>
<td>523,000</td>
<td>36,610</td>
</tr>
<tr>
<td>Sulfur</td>
<td>60</td>
<td>151,000</td>
<td>9,060</td>
</tr>
<tr>
<td>Potash (MOP)</td>
<td>95</td>
<td>268,000</td>
<td>25,460</td>
</tr>
<tr>
<td>Urea</td>
<td>100</td>
<td>74,000</td>
<td>7,400</td>
</tr>
<tr>
<td>NH(_3)</td>
<td>110</td>
<td>65,400</td>
<td>7,194</td>
</tr>
<tr>
<td>Ammonium sulfate</td>
<td>85</td>
<td>338,400</td>
<td>28,764</td>
</tr>
<tr>
<td><strong>Total Raw Materials Cost</strong></td>
<td></td>
<td></td>
<td><strong>114,488</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Utilities</th>
<th>(US $/kWh)</th>
<th>(units/year)</th>
<th>(US $1,000/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric power</td>
<td>0.07</td>
<td>48,600,000</td>
<td>3,402</td>
</tr>
<tr>
<td>Process water</td>
<td>0.85</td>
<td>140</td>
<td>0</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>102</td>
<td>4,900</td>
<td>500</td>
</tr>
<tr>
<td>Coating oil</td>
<td>600</td>
<td>3,000</td>
<td>1,800</td>
</tr>
<tr>
<td>Coating dust</td>
<td>200</td>
<td>10,000</td>
<td>2,000</td>
</tr>
<tr>
<td><strong>Total Utilities Cost</strong></td>
<td></td>
<td></td>
<td><strong>7,702</strong></td>
</tr>
<tr>
<td><strong>Total Variable Cost</strong></td>
<td></td>
<td></td>
<td><strong>122,190</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fixed Cost</th>
<th>(US $/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wages</td>
<td>5,819</td>
</tr>
<tr>
<td>Maintenance</td>
<td>7,655</td>
</tr>
<tr>
<td>Administrative and various cost (1% of investment)</td>
<td>3,901</td>
</tr>
<tr>
<td><strong>Total Fixed Cost</strong></td>
<td><strong>17,375</strong></td>
</tr>
</tbody>
</table>

#### Total Production Cost

<table>
<thead>
<tr>
<th></th>
<th>(US $1,000/year)</th>
<th>(US $/mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable cost</td>
<td>122,190</td>
<td>122</td>
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<tr>
<td>Fixed cost</td>
<td>17,375</td>
<td>17</td>
</tr>
<tr>
<td>Financial</td>
<td>31,212</td>
<td>31</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>170,777</td>
<td>171</td>
</tr>
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</table>
### Table 10. NPK (16-16-16) Plus CAN Production Cost

<table>
<thead>
<tr>
<th></th>
<th>Cost (US $/mt)</th>
<th>Sales Price (US $/mt)</th>
<th>Quantity (mt)</th>
<th>Cost (US $1,000/year)</th>
<th>Income (US $1,000/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPK (16-16-16) (MOP)</td>
<td>155</td>
<td>180</td>
<td>1,000,000</td>
<td>155,112</td>
<td>180,000</td>
</tr>
<tr>
<td>CAN</td>
<td>43</td>
<td>75</td>
<td>480,000</td>
<td>20,565</td>
<td>36,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>119</strong></td>
<td><strong>146</strong></td>
<td><strong>1,480,000</strong></td>
<td><strong>175,677</strong></td>
<td><strong>216,000</strong></td>
</tr>
</tbody>
</table>

#### Total Operating Costs

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Price (US $/mt)</th>
<th>Units/Year (mt)</th>
<th>Cost (US $1,000/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphate rock</td>
<td>70</td>
<td>493,000</td>
<td>34,510</td>
</tr>
<tr>
<td>Potash (MOP)</td>
<td>95</td>
<td>268,000</td>
<td>25,460</td>
</tr>
<tr>
<td>NH₃</td>
<td>110</td>
<td>356,000</td>
<td>39,160</td>
</tr>
<tr>
<td><strong>Total Raw Materials Cost</strong></td>
<td></td>
<td></td>
<td><strong>99,130</strong></td>
</tr>
<tr>
<td>Utilities</td>
<td>Price (US $/kWh)</td>
<td>Units/Year (mt)</td>
<td>Cost (US $1,000/year)</td>
</tr>
<tr>
<td>Electric power</td>
<td>0.07</td>
<td>75,000,000</td>
<td>5,250</td>
</tr>
<tr>
<td>Additives</td>
<td>2.30</td>
<td>480,000</td>
<td>1,104</td>
</tr>
<tr>
<td>Catalyst nitric acid</td>
<td>12.00</td>
<td>90,250</td>
<td>1,083</td>
</tr>
<tr>
<td>Coating oil</td>
<td>600.00</td>
<td>4,500</td>
<td>2,700</td>
</tr>
<tr>
<td>Coating dust</td>
<td>200.00</td>
<td>15,000</td>
<td>3,000</td>
</tr>
<tr>
<td><strong>Total Utilities Cost</strong></td>
<td></td>
<td></td>
<td><strong>13,137</strong></td>
</tr>
<tr>
<td><strong>Total Variable Cost</strong></td>
<td></td>
<td></td>
<td><strong>112,267</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fixed Cost</th>
<th>(US $1,000/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wages</td>
<td>4,981</td>
</tr>
<tr>
<td>Maintenance</td>
<td>10,572</td>
</tr>
<tr>
<td>Administrative and various cost (1% of investment)</td>
<td>5,318</td>
</tr>
<tr>
<td><strong>Total Fixed Cost</strong></td>
<td><strong>20,870</strong></td>
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</table>

#### Total Production Cost

<table>
<thead>
<tr>
<th></th>
<th>(US $1,000/year)</th>
<th>(US $/mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable cost</td>
<td>112,267</td>
<td>76</td>
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<tr>
<td>Fixed cost</td>
<td>20,870</td>
<td>14</td>
</tr>
<tr>
<td>Financial</td>
<td>42,540</td>
<td>29</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>175,677</strong></td>
<td><strong>119</strong></td>
</tr>
</tbody>
</table>
### Table 11. NPK (16-16-16) Plus AN Production Cost

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>Sales Price</th>
<th>Quantity</th>
<th>Cost</th>
<th>Income</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(US $/mt)</td>
<td>(mtpy)</td>
<td>(US $1,000/year)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPK (16-16-16)(MOP)</td>
<td>162</td>
<td>180</td>
<td>1,000,000</td>
<td>161,604</td>
<td>180,000</td>
</tr>
<tr>
<td>ANPP</td>
<td>47</td>
<td>175</td>
<td>350,000</td>
<td>16,608</td>
<td>61,250</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>132</strong></td>
<td><strong>179</strong></td>
<td><strong>1,350,000</strong></td>
<td><strong>178,212</strong></td>
<td><strong>241,250</strong></td>
</tr>
</tbody>
</table>

#### Total Operating Costs

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
<th>Price</th>
<th>Units/Year</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(US $/mt)</td>
<td>(mt)</td>
<td>(US $/1,000/year)</td>
<td></td>
</tr>
<tr>
<td><strong>Raw Material</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphate rock</td>
<td>70</td>
<td>493,000</td>
<td>34,510</td>
<td></td>
</tr>
<tr>
<td>Potash (MOP)</td>
<td>95</td>
<td>268,000</td>
<td>25,460</td>
<td></td>
</tr>
<tr>
<td>NH₃</td>
<td>110</td>
<td>356,000</td>
<td>39,160</td>
<td></td>
</tr>
<tr>
<td><strong>Total Raw Materials Cost</strong></td>
<td></td>
<td></td>
<td>99,130</td>
<td></td>
</tr>
<tr>
<td><strong>Utilities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric power</td>
<td>0.07</td>
<td>79,000,000</td>
<td>5,530</td>
<td></td>
</tr>
<tr>
<td>Bags</td>
<td>8.00</td>
<td>350,000</td>
<td>2,800</td>
<td></td>
</tr>
<tr>
<td>Additives</td>
<td>2.30</td>
<td>348,260</td>
<td>801</td>
<td></td>
</tr>
<tr>
<td>Catalyst nitric acid</td>
<td>12.00</td>
<td>90,250</td>
<td>1,083</td>
<td></td>
</tr>
<tr>
<td>Coating oil</td>
<td>600.00</td>
<td>4,100</td>
<td>2,460</td>
<td></td>
</tr>
<tr>
<td>Coating dust</td>
<td>200.00</td>
<td>10,000</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>ANPP coating agent</td>
<td>1.00</td>
<td>350,000</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td><strong>Total Utilities Cost</strong></td>
<td></td>
<td></td>
<td>15,024</td>
<td></td>
</tr>
<tr>
<td><strong>Total Variable Cost</strong></td>
<td></td>
<td></td>
<td>114,154</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed Cost</strong></td>
<td>(US $/1,000/year)</td>
</tr>
<tr>
<td>Wages</td>
<td>4,981</td>
</tr>
<tr>
<td>Maintenance</td>
<td>10,689</td>
</tr>
<tr>
<td>Administrative and various cost (1% of investment)</td>
<td>5,376</td>
</tr>
<tr>
<td><strong>Total Fixed Cost</strong></td>
<td>21,046</td>
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</tbody>
</table>

#### Total Production Cost

<table>
<thead>
<tr>
<th></th>
<th>(US $1,000/year)</th>
<th>(US $/mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable cost</td>
<td>114,154</td>
<td>85</td>
</tr>
<tr>
<td>Fixed cost</td>
<td>21,046</td>
<td>16</td>
</tr>
<tr>
<td>Financial</td>
<td>43,012</td>
<td>32</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>178,212</td>
<td>132</td>
</tr>
</tbody>
</table>
The above data and a debt-equity ratio of 50:50 were used to estimate the economics of each production scheme as related to net present value (NPV) and % IRR. A summary of the results follows:

<table>
<thead>
<tr>
<th></th>
<th>Phos-Acid Based</th>
<th>Nitrophosphate Based</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NPK Only</td>
<td>NPK (+) CAN</td>
</tr>
<tr>
<td>NPV (project)</td>
<td>(138,802)</td>
<td>(30,146)</td>
</tr>
<tr>
<td>NPV (equity)</td>
<td>(38,450)</td>
<td>103,153</td>
</tr>
<tr>
<td>% IRR (project)</td>
<td>8.07</td>
<td>12.23</td>
</tr>
<tr>
<td>% IRR (equity)</td>
<td>10.40</td>
<td>18.11</td>
</tr>
</tbody>
</table>

Note: NPVs are shown as US $1,000.

Figures 10 and 11 show the effect of variations in CAN and AN (explosive grade) prices on the percent IRR for the total project.

---

**Conclusion**

Based on the previous calculations and assumptions, it can be stated that the economics of producing NPK 16-16-16 grade and CAN or explosive-grade AN in a nitrophosphate plant is more viable financially than producing a single NPK 16-16-16 product in a wet process phosphoric acid-based plant. This conclusion could be significantly different based on actual conditions at the plant site, the actual sales price of the products, and plant location in relation to the market area.

**Figure 10. Economics in Production of Nitrophosphate NPK Plus CAN.**
Figure 11. Economics in Production of Nitrophosphate NPK Plus Ammonium Nitrate Explosive Grade.
Introduction

Scientists have known for almost 200 years that certain gases in the earth’s atmosphere act as an insulating blanket, keeping surface temperatures warmer than would otherwise be the case. Almost 100 years ago Arrhenius postulated that large-scale burning of fossil fuels could raise the concentrations of these “greenhouse” gases (GHGs), most notably carbon dioxide (CO₂), and thus raise the earth’s temperature above natural levels. Although careful measurements established that CO₂ concentrations were indeed rising as a result of human activity, it was not until the 1970s that the possibility of global climate change began to attract more serious scientific attention and even more recently that the subject has concerned political leaders.¹

Greenhouse gases are released in connection with a wide range of human activities. Carbon dioxide is produced when fossil fuels are burned to release their stored chemical energy and when forests are cut down. Emissions of methane and nitrous oxide can be traced to agricultural activities, changes in land use, and other sources. Manmade chemicals, called halocarbons, which contain chlorine, bromine, and fluorine, and other long-lived gases such as sulfur hexafluoride (SF₆) are released in industrial processes and from the manufacture and use of consumer appliances and industrial equipment.

Climate models predict that the global temperature will rise by about 1° to 3.5°C by the year 2100, a climatic change larger than any experienced over the last 10,000 years. This estimate is based on current emission trends and assumes that no efforts are made to limit greenhouse gas emissions. There are many uncertainties about the scale and impact of climate change, particularly at the regional and certainly at the local level. Because the oceans absorb a great deal of heat, they delay the effects of climate change: surface temperatures do not respond immediately to greenhouse gas emissions, and temperature increases will continue for many decades after atmospheric concentrations have stabilized.

The impact of climate change varies and includes species extinction brought about by climate-induced stresses on forests, deserts, rangelands, and other unmanaged ecosystems; flooding of low-lying areas; damage to physical infrastructure; and greater variability in the availability of water resources. In all countries, the poor and disadvantaged will be the most vulnerable to the negative consequences of climate change.

The International Response

International attention to the issue of climate change began in the late 1970s with a series of scientific conferences and the creation of expert bodies, the most well known of these being the Intergovernmental Panel on Climate Change (IPCC). The IPCC was established in 1988 by UNEP and the World Meteorological Organization (WMO) with a mandate to assess the state of existing knowledge about the global climate system and climate change; the environmental, economic, and social impacts of climate change; and the possible response strategies. IPCC released its First Assessment Report in 1990 and confirmed the scientific evidence for climate change. This report had a powerful effect on both policymakers and the general public and provided the basis for deliberations on the United Nations Framework Convention on Climate Change (UNFCCC), negotiation of which was approved by the UN General Assembly in 1990.

The UNFCCC was adopted in 1992 and now has 170 Signatory
Parties. The Convention seeks to stabilize atmospheric concentrations of greenhouse gases at safe levels. It commits developed countries to take measures aimed at returning their emissions to 1990 levels by the year 2000, and requires all countries to limit their emissions, gather relevant information, develop strategies for adapting to climate change, and cooperate on research and technology development.

The IPCC adopted its Second Assessment Report in December 1995. Published in time for the second meeting of the Parties to the UNFCCC, the Second Assessment Report was written and reviewed by some 2,000 scientists and experts worldwide. It quickly became known for its conclusion that “the balance of evidence suggests that there is a discernible human influence on global climate.” The Report also confirmed the attractiveness of so-called no-regrets options and other cost-effective strategies for combating climate change.

Recognizing that the UNFCCC did not go far enough to protect the climate system, Parties to the Convention strengthened it through the 1997 Kyoto Protocol. Over 10,000 delegates and observers attended the meeting in Kyoto, Japan, and in last-minute negotiations delegates agreed on a text. By placing legally binding limits on greenhouse gas emissions, the Kyoto Protocol attempts to reverse, in developed countries, the upward trend in greenhouse gas emissions that started during the industrial revolution.

**The Kyoto Protocol**

Under the terms of the Kyoto Protocol, the developed countries have committed themselves to reduce emissions of six types of GHGs by various targets that differ from country to country. The average of slightly over 5% masks large differences in obligations, however, which range from a decrease of 8% by the European Union (EU) to an allowed increase of 10% for Iceland. The six gases are combined in a “basket,” with reductions in individual gases translated into “CO₂ equivalents” that are then added to produce a single figure.

Each country’s emission target must be achieved on average by the period 2008–2012; the purpose of the range is to allow for fluctuations in economic performance or other circumstances that might affect fossil fuel use in any single year. Demonstrable progress in reaching the various targets must be made by 2005. Reductions in the three most important gases—carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O)—will be measured against a base year of 1990 with exceptions for some countries with economies in transition. Decreases in three long-lived industrial gases—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆)—can be measured against either a 1990 or 1995 baseline.

In that emissions levels would increase without the Protocol, actual emission reductions required from the baselines will be much larger than 5%. Compared with the emission levels projected for 2010 without control measures, the Protocol target represents a reduction in GHG emissions of more than 30%. Exactly how the international obligations will be met domestically is left to each country. Most seem inclined to use a combination of fiscal policies, voluntary and government programs, and direct regulation.

Countries are given a degree of flexibility in how they make and measure their emission reductions. The three “flexibility mechanisms” in the Kyoto Protocol will reduce the overall cost of meeting the Protocol’s targets by allowing some control measures to be taken where they are less expensive. From an environmental standpoint, emissions of the long-lived GHGs are blind as to the country of origin, that is, they are well mixed in the atmosphere over the time scales of concern, and only the magnitude of emissions, not their source, matters. Reducing emissions where they are less costly will yield the same environmental benefit at a lower burden to society.

The international emissions trading regime to be established under the Protocol will allow industrialized countries to buy and sell emission credits among themselves. They will also be able to acquire “emission reduction units” by financing certain kinds of projects in other developed countries under the provision of the Protocol referred to as Joint Implementation. Finally, a Clean Development Mechanism (CDM) will enable industrialized countries to finance emissions-reduction projects in developing countries and to receive credit for doing so. The operational guidelines for these various schemes must still be further elaborated and are now being debated by countries.

The Protocol encourages governments to cooperate with one another and to improve energy efficiency, reform their energy and transportation sectors, promote renewable forms of energy, phase out inappropriate fiscal measures and market imperfections, limit methane emissions from waste management and energy systems, and protect forests and other carbon sinks. The measurement of change in net emissions (calculated as emissions minus removals of CO₂) from forests is methodologically complex and still needs to be clarified.
Global Cooperation on Technology Transfer

As the preceding discussion makes clear, climate change is a global problem that requires a global solution. Developed countries account for the largest part of historical and current greenhouse gas emissions; their share for 1994 was about 75% of the global total. Of concern, however, is that while per-capita emissions in developed countries are likely to stabilize at well above the world average, developing-country emissions continue to rise steadily and are expected to represent half of the global total before the year 2025.

Even in the absence of the Convention and Protocol, most growth in GHG emissions would occur in developing countries. These countries will have to adopt climate-friendly technologies if they are to establish a low-emission industrial infrastructure and maintain a low growth trajectory for emissions. Under the UNFCCC, the richest countries, essentially the Organization for Economic Cooperation and Development (OECD) members, have agreed to “take all practical steps to promote, facilitate, and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the Convention.” How best to do this and the level of effort required by the Convention are at present matters of intense debate and discussion.

Technology can be transferred to developing countries through several different channels. The most commonly used channels in the past have been bilateral and multilateral development aid in the form of export credits, insurance and other trade support, loans, and technical training or capacity-building efforts. There is currently a push to involve various private-sector entities to a greater extent in the formal mechanisms established under the UNFCCC. Their involvement is needed because much of the necessary technical expertise and investment capital can be found in private-sector companies and because private-sector investment has eclipsed the role of governments in resource transfers to developing countries.

To be effective, technology transfer must be accompanied by capacity building. The delivery of new hardware alone rarely leads to “real, measurable, and long-term environmental benefits” in the host country as called for by the Convention. In many situations, it is essential to strengthen existing local institutions. This includes building managerial and technical skills and transferring the capacity for operating and replicating new technological systems on a sustainable basis. Capacity building also has a role to play in ensuring that new technologies are, in the words of the Convention, “compatible with and supportive of national environment and development priorities and strategies, [and] contribute to cost-effectiveness in achieving global benefits.” Industry again has an important role to play in capacity-building efforts.

As noted above, the Kyoto Protocol provides for a so-called Clean Development Mechanism, which is intended to help developing countries achieve sustainable development and contribute to the Convention’s goals. Although the details are yet to be worked out, CDM projects will result in “certified emissions reductions” that developed countries can use to meet their binding emissions targets. CDM projects in principle can involve private or public entities and must lead to real and measurable long-term emissions-limitation benefits. A number of industries in developed countries are helping to define the modalities so that the CDM becomes a useful mechanism from their point of view.

Next Steps

At the fourth meeting of the Parties to the Convention on Climate Change, held in Buenos Aires in November 1998, the Parties agreed on an ambitious work program (the Buenos Aires Plan of Action) to resolve many of the Kyoto Protocol’s outstanding issues, including the following:

- Rules for the flexible mechanisms (emission trading, joint implementation, and the CDM).
- The financial mechanisms that will be established to assist developing countries.
- The development and transfer of technologies.
- The issue of compensation for adverse effects of climate change and mitigation policies.
- Compliance and enforcement.

Parties aim to complete negotiations over these issues by the end of 2000, when the sixth meeting of the Parties is planned.

The fertilizer industry and its representative associations should participate actively in the continuing international debate about the mitigation of climate change, including determining the details of the Kyoto Protocol. Judging by its proactive environmental efforts, successful technology transfer programs, and willingness to work cooperatively on issues of common interest, the fertilizer industry has much to offer.
Introduction

AGRA CZ, a stock company, is currently one of the leading companies in the field of foliar fertilizers in the Czech Republic. The company is a producer of foliar fertilizers that bear the CAMPOFORT trademark. The production of these fertilizers is the main function of the AGRO division, and this operation is the most dynamically developing component of AGRA CZ. Another part of the production structure of our company is the Organic Production Division, which is the largest European processor of organic material of animal origin, such as cattle horns. The third division is the Hobby Division, which handles the production of organic and organic-mineral fertilizers.

The AGRO Division has 27 employees with an additional 12 coworkers participating in the development and marketing branch. All of these employees are highly qualified experts in agronomy with specialization in individual agricultural commodities.

To illustrate the current situation of the company, the distribution of personnel costs within the AGRO division, is given in the following table.

<table>
<thead>
<tr>
<th></th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative offices</td>
<td>26</td>
</tr>
<tr>
<td>Production</td>
<td>24</td>
</tr>
<tr>
<td>Sales</td>
<td>15</td>
</tr>
<tr>
<td>Development and marketing</td>
<td>35</td>
</tr>
</tbody>
</table>

It can be seen that a large portion of the expenditures is devoted to development and marketing because it is recognized that only products that are competitive on the global world market will ensure long-term dynamic development of the company. The narrow specialization in development and marketing in the field of foliar fertilization should assist the company, which is still relatively small, to join the world market for specialty fertilizers. The actual results achieved thus far indicate that the rather high investment by the company in development and marketing of foliar fertilizers will result in good financial returns in the future.

To understand what actually has led the company to become involved in a production program in the agricultural sphere, specifically in the field of crop production, it is necessary to review the origin of the company in 1992. The primary decision to be oriented to agriculture and crop production was influenced by the activities of the former state enterprise that was assimilated into the AGRA company in 1992.

However, substantially more time was needed to arrive at a definite decision concerning the long-term and narrow specialization in the field of foliar nutrition. The following factors led the AGRA company to specialize in foliar nutrition:

- A thorough and detailed analysis was made of the company’s current practice related to the structure and nature of all costs within the framework of the crop production system.
- Besides the analysis that was made based on our own practice, it was necessary to investigate existing conditions, particularly with respect to professional potential inside the agricultural sector within the Czech Republic. It was concluded that the available equipment and professional expertise in the field of plant nutrition already existing in the Czech Republic could be used as a base for building a long-term production program geared to the developing needs of agriculture.

After evaluation of all information gathered by investigations, it was obvious that it would be advantageous for the company to specialize in foliar nutrition for the long term. In addition, it was clear that optimum foliar nutrition must be integrated into the Best Agriculture Practices (BAPs) program. It is likely that implementation of the basic ideas contained within the BAPs is the surest way to solve the current...
problems of Czech agriculture and make it competitive. These conclusions should also apply to other countries of Central and Eastern Europe.

The following discussions will include the current and future plans of the company, details of problems to be solved, and the desired results from foliar nutrition. Simply, answers are being sought to the following questions:

1. Is the cost currently spent in time and place in the field of plant nutrition adequate, optimum, and accurately defined for the future?

2. Are current recommendations in the field of plant nutrition optimum regarding the applied amount of nutrients, ratios of nutrients, or the form of their application to be able to fully stimulate built-in genetic potential in a plant?

From the company’s perspective, the answer is no, at least where the appropriate foliar nutrition has not become a firm and essential part of the process of general plant nutrition.

Our negative answer is based on several years of repeated positive results with CAMPOFORT foliar fertilizers, which confirmed the fact that the main advantages of appropriate foliar nutrition, meaning foliar nutrition optimally applied, are as follows:

- Overcoming obstacles that limit supply of nutrients through the roots. The obstacles include drought, strong nutrient fixation in the soil, and any antagonisms (unwanted nutrient interactions). For example, excessive content of potassium in soil results in preferential potassium uptake and suppression of uptake of other nutrients, such as magnesium.
- Regeneration of plants damaged by unfavorable climatic conditions, diseases, or pests.

The most important aspects of the eight types of CAMPOFORT’s foliar fertilizer products (Table 1) are discussed below. To point out the contribution that the CAMPOFORT foliar fertilizers have for the Czech farmers, details are given of the economic advantages of application of foliar fertilizers.

The main economic benefit of CAMPOFORT fertilizers is their relatively high rate of return of the financial resources invested in their application. As expected, the result is different for various agricultural commodities; however, actual experience since 1994 has shown that the average return ratio is 5:1 (benefit to cost). Returns of 10:1 are not unusual for root crops such as potatoes and sugar beet. The main reasons for this economic advantage or high return are as follows:

- Relatively low doses of foliar fertilizers required per unit of area.
- Relatively low cost of fertilizer production using a simple technology (see Figure 1).

The foliar fertilizers are produced from readily available chemical products and compounds, such as urea, calcium nitrate, various kinds of salts, and acids in crystal or powder form that are carriers of basic macronutrients and micronutrients in foliar fertilizers. Another component of the CAMPOFORT fertilizers is a compound developed by the company named Agent Improving Genetic Potential (AIGP). Production of AIGP is protected by a Czech patent. The technology is rather simple, and more importantly, the basic raw material needed for the production is available in the Czech Republic.

The production process is based on optimum selection of the individual components, their appropriateness to preprocessing, feeding of exact quantities, homogenization, and proper packing. There are no compli-

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>MgO</th>
<th>Zn</th>
<th>CaO</th>
<th>S</th>
<th>Mn</th>
<th>B</th>
<th>Micronutrients a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special B</td>
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<td>6</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Special Mn</td>
<td>22</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special Zn</td>
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<tr>
<td>Garant P</td>
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<td>24</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Plus</td>
<td>22</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forte</td>
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<td>8</td>
<td>5</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Main Foliar Fertilizer Grades Produced by AGRA CZ a.s. (Trade Name: CAMPOFORT)

a. Micronutrients include Mg, B, Mn, Fe, Cu, and Zn.
cated technological processes that would either increase the costs of production or create a negative effect on the environment. Minimization of the environmental impact reinforces the advantage of using a simple production technology.

Environmental Considerations

Two main problems had to be solved to lessen the environmental impact of the applied technology:

- To ensure recycling of the packaging material in which the beginning materials are supplied.
- To prevent escape of gases and condensates into the environment.

Both problems have been successfully solved. The technology of the foliar fertilizer production does not show any ecological problems, and the application of foliar fertilizers in agriculture is environmentally friendly.

Summary

In summary, AGRA CZ is convinced that based on our long-term agrochemical experience, foliar fertilizers do not represent any serious ecological problems, from both the production and application standpoints. Furthermore, they can be considered as very effective tools in modern agricultural production. The most advanced systems developed for using them, such as the BAPs, plant nutrition management, balanced nutrition, and others, should include actual application of the foliar fertilizers. Therefore, current plans by the company are to initiate the general implementation of application of foliar fertilizers into the above-discussed systems. For this purpose international cooperation is being sought from world organizations and professional partners to further the development and production, use, and application of foliar fertilizers.
Use of Fertilizers and Problems of Maintaining a Sustainable Agrarian System in the Slovak Republic

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Central Agricultural Inspection and Testing Institute
Slovak Republic

Introduction

All agricultural activities have their natural beginning in the soil. Experience in the Slovak Republic substantiates this view. Entire generations of active farmers and experts of related biological and technical sectors, primarily experts in fertilizer chemistry and agrarian equipment, have focused their attention on the fertility of soil.

The importance of soil fertility, as a prerequisite for maintaining the quality of life on our planet, is also stressed by Agenda 21, an important document of the last decade. The birth of the concept of the connection between fertilization intensity, reserves of acceptable nutrients in soils, and crop yields in the second half of the 20th century in our country can serve as an example of the importance of soil fertility parameters.

Post-World War II Period

Before large cooperatives were established in the 1950s and 1960s, the post-war period could be characterized by: (1) a very low level of inputs, (2) low use of machinery, (3) use of traditional farming methods based on empirical information with the dominant effect of weather during dry years, and (4) an agricultural products market influenced by scarcity. Having a centrally planned economy, the state had two goals—to increase the efficiency of agriculture and gradually to reach food self-sufficiency. The methodology chosen included increasing soil fertility using soil testing for the entire country.

In 1956, the first of the 5-year cycles of agrochemical soil testing (ASP) was started, and the program continues today. In year 2000, the 11th cycle of soil testing will begin.

The results of the first cycle showed a high proportion of acid soils and low reserves of needed plant nutrients. Significant projects followed for improving soil fertility beginning with liming of acid soils and complementary activities such as building drainage and irrigation systems on large acreages of quality soils. Implementation of these projects was based on results obtained from complex scientific soil research, which was completed at the end of the 1960s.

However, production intensity remained low in the state establishments and large cooperatives (with acreage up to 5,000 ha), mainly due to low usage of commercial fertilizers prior to the 1970s. One reason was a shortage of domestically produced fertilizers in the former Czechoslovakia.

Superphosphate was the only fertilizer produced in the Slovak Republic after World War II. Following the startup of plants for production of saltpeter, urea, and NPK fertilizers, especially during the 1970s, total production exceeded domestic consumption. Part of the production of N and NPK fertilizers was supplied to adjacent areas in the Czech Republic, and fertilizers were also exported.

A sufficient supply of relatively cheap fertilizers stimulated increases in consumption, which also translated to increased yields and increased soil fertility (Table 1). The rising content of acceptable nutrients in the soil was documented by results of ASP. Crop yields increased similarly, especially cereals that averaged more than 5 mt/ha. Considering the biophysical constraints associated with the soils and climate, this yield may represent close to the maximum economic yield.

Saturation of the fertilizer market stimulated producers to search for new products and production methods to increase demand. After preliminary agronomic evaluation, the production of liquid N and NP types of fertilizers, UAN, and ammonium ortho and polyphosphates was begun in the late 1970s. NP and NPK suspensions were also produced in smaller quantities. Liq-
uid fertilizers became a part of cultivating technologies to such an extent that after 1985 their consumption reached 40% of the total nitrogen use and 20% of phosphorus. In this period, the consumption of fertilizers reached its maximum historical value of approximately 260 kg of NPK per hectare. Self-sufficiency was achieved in agricultural commodities, and gradually a surplus market was established.

Liquid fertilizers made possible a more effective use of nutrients, which translated into increased yields and improved efficiency of the agricultural sector. Merging of operations resulted in a significant saving of labor and ma-

chine operation. Liquid fertilizers, in concentrated form or diluted in water, provide a very good medium for the application of pesticide compounds. Thus, it is possible to reduce the application costs and increase the uniformity of application through the field. In addition, a synergistic effect of compounds in the form of increased effectiveness of pesticides is obtained, thus allowing a decrease in the applied dosage. The positive side effects of the liquid fertilizers include better handling characteristics, improved occupational safety and health at work, and enhanced protection of the environment.

The level of yields and fertilizer use that was achieved with liquid fertilizers also led to the application of trace elements. Liquid nitrogen fertilizers serve as a good carrier of either one-component materials, premixes of microelements, or specially formulated fertilizers. The advantages of liquid fertilizer application by large cooperatives were so convincing that these products were widely used by the cooperatives in the mountainous conditions that prevail in the Slovak Republic.

Table 1. Evolution of Average Cereal Yields and Fertilizer Consumption of Slovakia (1950-98)

<table>
<thead>
<tr>
<th>Year</th>
<th>mt grain/ha</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>1950</td>
<td>1.47</td>
<td>5.60</td>
<td>7.60</td>
<td>10.10</td>
<td>23.30</td>
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<td>1955</td>
<td>1.81</td>
<td>11.90</td>
<td>11.10</td>
<td>17.50</td>
<td>40.50</td>
</tr>
<tr>
<td>1956-60</td>
<td>1.91</td>
<td>11.82</td>
<td>13.12</td>
<td>21.88</td>
<td>46.82</td>
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<tr>
<td>1961-65</td>
<td>1.94</td>
<td>21.02</td>
<td>25.70</td>
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<tr>
<td>1977</td>
<td>4.03</td>
<td>77.60</td>
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<td>8.8</td>
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</tr>
</tbody>
</table>

Developments Following Introduction of a Free Market System

Social and political changes after 1989 resulted in transformation of the agricultural sector. Disintegration of large cooperatives, restitution of original property rights, and decreasing state subsidies to the agricultural sector (well below the normal level in the European Union [EU]) represented the starting points of an agrarian crisis, which persists today. Expansion of subsidized foodstuffs, especially imports from the EU countries, also contributes to this crisis. The country was not prepared for the abrupt introduction of a free market.

Farmers continue to lose their domestic market and suffer from insolvency that is reflected in the radical reductions of inputs for production, as the prices of production inputs skyrocket compared with stagnating prices of outputs from production. Reduced use of fertilizers was the first victim during the cost-saving regime, which had the goal of retaining approximately two-thirds of former yields with nitrogen fertilizer only. The reasoning for such action during the first years of the cost-saving regime was based on the fact that there were sufficient reserves of nutrients in the soil (in
Another indication is the decreased contents of phosphorus (Figure 2) and potassium (Figure 3), which is a common problem in almost all of the soils. This situation combined with decreasing soil reaction—not only acidification and alkalinization as a result of a decreased application rate of fertilizers—has an adverse effect on the natural alkalinity of soils. The question is “How long can this situation continue?”

Regarding consumption of fertilizers in our country, the two extremes of development discussed above clearly illustrate the intensified effect of fertilizer use on quantity and quality of yield and on the efficiency and resistance of an agricultural production system. Based on research related to fertilization practices, the strategy of fertilizer use has changed dramatically. Preference is given to nitrogen nutrition, and higher fertilizer application rates are recommended for the more marketable crops and for such soil sites where an additional input of fertilizers can be effectively translated into financial gains.

To maintain profitable operations, farmers must establish economically efficient systems of farming, using all potential reserves of nutrients including biological fixation and use of farm fertilizers and byproducts. Caution must be used regarding possible use of liquid fertilizers and suspensions because the necessary controls must be implemented.

**Conclusions**

Consumption of fertilizers, derived from domestic requirements of agrarian production or export possibilities, should reach a level that allows for the following:

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**Figure 1. Nutrient Input and Wheat Yields Under Different Growing Conditions.**
Figure 2. Evolution of P Consumption and Resources in Arable Land of Slovakia, by the Cycles of Agrochemical Soil Testing.

Figure 3. Evolution of K Consumption and Resources in Arable Land of Slovakia, by the Cycles of Agrochemical Soil Testing.
• The nutrients removed from the soil to achieve desired crop yields are replaced.

• An optimal level of soil fertility (pH, nutritive regime) is retained, considering the soil, climatic and production conditions, and structure of plant production.

• Hygienic limits and ecological restrictions are strictly respected in relation to type, dosage, date, and method of fertilizer application.

• Permanent soil fertility, production efficiency of the soil, and stability of the cultivating system in the company (region, state) are maintained.

• Conditions for proportional stability (development) of the entire agrosystem are created.
Environmental and Economic Benefits of Enhanced Efficiency Nitrogen Fertilizers Tailored to Commercial Cropping Systems

James T. Pursell, Chairman
and John H. Detrick, Vice President Technology
Pursell Technologies Inc.
Sylacauga, Alabama, U.S.A.

Introduction

This paper focuses on a new polymer-coated urea (PCU) and on the environmental and economic benefits derived from its use as a controlled-release nitrogen (CRN) fertilizer with enhanced nitrogen efficiency tailored to commercial cropping systems. The following four questions about this controlled-release nitrogen, POLYON® PCU, are answered.1

What is POLYON PCU?

POLYON is the brand name for the PCU product produced by a unique reactive layers coating (RLC™) process, which is a breakthrough in polymer coating (encapsulating) technology. In this paper reference to the brand name, POLYON, means POLYON PCU, unless otherwise noted.

What does POLYON do?

The contribution of POLYON controlled-release nitrogen to pollution prevention, by reducing surface runoff and leaching of nitrates, is reviewed. Also, what it can do for the farmer, through enhanced plant uptake of nitrogen to produce increased crop yields and improved profits, is discussed.

How does POLYON do it?

It will be shown that POLYON controlled-release nitrogen can replace some of the water-soluble nitrogen, which is at greater risk of nitrate loss to the environment.

In addition, since the POLYON polymer coating controls the release of the urea into the soil solution, an enhanced, more efficient uptake of the urea nitrogen by the plant is effected, which reduces the opportunity for nitrogen loss to groundwater.

How is POLYON Made by the Patented RLC Process?

A review of this new polymer coating process using the reactive layers coating process is presented. Some of the unique processing features and economic benefits of this RLC process to produce POLYON PCU are discussed.

The POLYON PCU Technology

POLYON PCU is produced by a reactive layers coating process, or RLC process, which is a breakthrough in ultra-thin polymer coating technology. This patented RLC process coats granular urea with ultra-thin polymer coating membranes, which are less than the thickness of a human hair, usually in the range of 15 to 35 µm (.015-.035 mm). As will be seen later in this paper, these thinner coatings have a pronounced effect on keeping the PCU nitrogen costs low. Other coated fertilizer technologies, which have been developed and introduced in Europe and Japan, have comparatively thick polymer coatings. These other technologies apply a solvent-dispersed polymer liquid onto NPK fertilizer prills or granules. The liquid dries by solvent evaporation, yielding a comparatively thick polymer coating. These polymer types either are alkyl resins or polyolefins. Urea granules can be, and sometimes are, coated by using these solvent process coating technologies, but again the polymer coatings that are applied by these processes are comparatively thick. The coating membrane on POLYON principally is a polyurethane, a polymer known for its toughness and durability, which ensures the reliability and predictability of release control. The POLYON coating can withstand blending, conveying, and other rough handling without significantly affecting its nutrient release characteristic.

The release time of POLYON is controlled by the polymer coating thickness applied in the RLC process. The ultra-thin polymer membrane is applied onto the urea at specified, controlled

1. Presented paper.
2. POLYON is a registered brand name, and RLC is a trademark.
thicker than in controlled-release nitrogen are requirements imposed on PCU technology in commercial use in the United States. The brand name POLYON AG PCU is used in agricultural crop applications, and POLYON PCU is used for lawn and garden and professionally managed turfgrass, such as golf courses. The POLYON brand and logo were on some 25 million bags of homeowner turfgrass fertilizers sold in 1999 through retail stores in the United States. Many golf course turfgrasses are fertilized with POLYON PCU technology.

The RLC process and POLYON PCU technology have the potential to break through the economic barrier that previously has prevented other PCU technologies from gaining applicability and economic acceptance for large-scale agricultural crops. The performance and economic requirements imposed on PCU controlled-release nitrogen are much more challenging in agriculture cropping systems than in horticulture applications. The ultra-thin, durable, polymer coating technology of POLYON represents a breakthrough that can meet these challenges.

Agriculturally focused universities in the United States are intensifying research directed toward finding solutions to the nitrate pollution problems and are increasing testing and research with controlled-release nitrogen fertilizers, particularly POLYON. Although the farmer is interested in nitrate pollution prevention, his fundamental interest is in increasing economic crop yields. So the research objectives are underscored with economic rationalization. This university and on-farm research in the United States includes corn, wheat, soybeans, cotton, rice, and vegetable and fruit crops with a focus on areas where cropping practices, soil types, and climate show increased potential for nitrate pollution.

When properly applied, or tailored to the cropping system, POLYON can help in the prevention of pollution problems by reducing surface runoff of nitrogen and leaching of nitrates into the groundwater. The application of some amount of POLYON controlled-release nitrogen replaces and thereby reduces the application of soluble nitrogen, which is at greater risk of nitrate leaching into the groundwater. The precision placement of the POLYON in the soil, in the developing root zone of a crop, increases the opportunity for nitrogen uptake by the crop from the controlled-release delivery of nitrogen from the POLYON PCU. This greater uptake of controlled-release nitrogen further reduces the risk of nitrate leaching to the groundwater. When the plant more efficiently takes up nitrogen, as a result of the precision placement and controlled-release nitrogen delivery from the POLYON, this enhanced efficiency of nitrogen uptake by the plant increases its growth and crop yield potential while reducing the risk of leaching loss. Higher crop yield can mean more profit for the farmer. Determining the proportionate amounts of soluble nitrogen and controlled-release nitrogen needed to maximize crop yield has been the thrust of the university research and on-farm trials.

Many farmers are interested in experimenting with CRN fertilizer because they are aware of potential environmental legislation that might require its use. For example, in one state in the United States, there is a proposed change in the law that will require a 20% reduction in the recommended nitrogen used to grow a crop. There is also concern about the hypoxia (dead zone) in the Gulf of Mexico, at the mouth of the Mississippi River. Contributing to the hypoxia problem are fertilizer nitrates coming from many tributaries feeding into the Mississippi River, which transports and drains nitrates to the Gulf. Similar nitrate pollution concerns and conditions exist in many countries throughout the world.

Nitrate escapes into the groundwater environment from a range of sources, which include among others, animal droppings, decomposition of organic matter, and nitrogen fertilizers. A goal of the fertilizer industry is to focus on those areas for which improvements are needed and where it can have an effect or can exercise control. Management of nitrogen fertilization methods or practices is one such area. Growers and fertilizer dealers need to have the flexibility within the framework of best management practices (BMPs) to select those fertilization practices that have good probability of resulting in both acceptable environmental impact and improved productivity.
Problems associated with nitrate pollution will be solved by farmers implementing processes, methods, and practices that are intended for their solution. One fertilizer nitrogen management tool being given consideration in this regard is the “enhanced efficiency” fertilizer, which is described in a proposed policy statement by the Association of American Plant Food Control Officials (AAPFCO) in its official publication. Among the various “enhanced efficiency” fertilizers described in the AAPFCO official publication are the granular PCU fertilizers, which generally are considered to be the most efficient of the currently available slow- or controlled-release nitrogen fertilizer technologies.

Release efficiencies of several types of CRN fertilizers were tested including PCU, sulfur-coated urea (SCU), and aldehyde-urea reaction products including urea-formaldehyde (UF), and urea-isobutyraldehyde (UIB). It was reported that the quantity of N released was lowest for UF 38N and highest for POLYON PCU 43N, which had a gradual release and essentially complete release during the 16 weeks of the test [1]. Plants or crops cannot respond to unreleased, or extremely slow releasing fractions of CRN fertilizers, such as the high-molecular-weight fractions of UF 38N fertilizers.

The farmer can help alleviate nitrate pollution problems through the use of controlled-release nitrogen as part of the total nitrogen fertilizer applied. The increased yields that result have the potential of making these practices cost-effective. Greater nitrogen uptake by the crop can mean an increase in yields and an increase in profits, as well as a decrease in the impact of escaped nitrogen on the environment. POLYON controlled-release nitrogen may become another link in the chain of precision farming.

Precision nitrogen management practices through the placement of starter nitrogen fertilizers and nitrogen-phosphate fertilizers, to reduce N-loss and increase crop production, are documented in agronomic research publications. Placement of small amounts of these starter fertilizers in a narrow band near the seed, or even in the seed furrow, at time of planting can be both operationally effective and economically productive, improving yields and crop quality. However, there is a potential risk for injury to the germinating seed, or to the seedling, if there is direct contact between seed and fertilizer in these types of fertilizer placements at time of planting. Even when some soil separates seed and fertilizer, as it does in a side-by-band, the risk of seed injury remains if the rate of N-fertilizer application is too high, or the soil moisture is too low, or the texture of the soil is too coarse, as with sandy soils.

The growing importance of reduced tillage and no-till practices has been accompanied by an increased emphasis on the application and placement of nitrogen fertilizers at time of seed planting. The nitrogen fertilizers can be placed directly in the seed furrow or in the side-by band, called a “2 x 2 band,” which commonly is 2 inches (50 mm) to the side and 2 inches (50 mm) below the seed. With either of these placement practices there can be a risk of seed germination damage, but clearly the risk is higher when the fertilizer and seed are applied directly into the seed furrow.

The type and placement of nitrogen fertilizer to be used are important considerations. In situations where farmers use grain drills or planters and place fertilizers in contact with the seed, the sum of the N plus K₂O application usually has a recommended limit. For soybeans, which are very prone to fertilizer salt injury, fertilizer placement with the seed is not recommended.

Granular urea can be inefficient and can pose risk under certain use conditions. Ammonia volatilization losses from unincorporated granules, ammonia toxicity to germinating seeds or seedlings, and urea granule wetness under moderate humidity conditions, which adversely affects handling and application, are some of the problems associated with urea.

To minimize or even eliminate these adverse urea characteristics, the ultra-thin polymer coating of the POLYON PCU is all that is required. This polymer-coated urea can be used as a controlled-release nitrogen in a side-by band at significantly higher than customary N-rates without risk of seed injury. The controlled-release urea-N from this PCU, which is positioned in the developing root zone, will be available and completely released during the time of plant demand and crop growth. This precision placement of controlled-release PCU-N will result in more efficient N-uptake and correspondingly increased crop yield.

There will be an increased input cost per acre when part of the total-N to be applied is replaced with PCU-N. However, the increased yield can more than offset the added input cost. The per-acre or per-hectare dollar value of the increased crop yield, as a result of more efficient nitrogen uptake, can exceed the additional incremental cost per acre or hectare resulting from the use of the PCU.

How POLYON Does It

Imagine that each PCU granule is a tiny container or vessel holding urea. Each relatively spherical PCU vessel, which has
a thin polymer wall construction, contains one undissolved urea granule. The thin polymer wall functions as a membrane, in much the same way as the membranes of the epidermis cells on the surface of a plant root. The membranes of these root cells absorb water and nutrients from the soil. The PCU vessel is a membrane-encapsulated urea cell, which also absorbs water from the soil and dissolved urea from inside the PCU cell. When these tiny polymer-walled PCU vessels are placed in moist soil, or for that matter immersed in water, the polymer wall of the vessel will begin to absorb moisture. The rate at which water is absorbed by the polymer wall, e.g., the polymer coating of the PCU, depends upon the permeation characteristics of the specific polymer and its thickness.

An osmotic diffusion mechanism is established with the thin polymer wall functioning as a membrane, which provides a constant, gradual diffusion of nutrients through the polymer coating. The absorption of soil water into the PCU and the release of dissolved urea from the PCU are controlled by the thickness of the coating membrane.

A PCU with a polymer coating that is twice as thick as a polymer coating on another PCU will take twice as long for water to be absorbed fully into the polymer coating. This absorption of water is necessary before the dry granular urea, which is encapsulated in the PCU vessel, can begin to dissolve and begin its release. During this initial water absorption stage, urea is not being released. This delay of urea release following PCU application to the soil is also referred to as the induction phase. When the initial increment of absorbed water reaches the urea granule encapsulated within the PCU, it will dissolve a small increment of the urea granule, which will be at saturation concentration. An osmotic diffusion mechanism is established with the endosmosis of water into the PCU and the exosmosis of dissolved urea from the PCU through the membrane coating. The rate of diffusion of dissolved urea through the polymer membrane coating is driven by its high solution concentration of urea inside the PCU.

It may not be readily apparent, but the amount of soil moisture, rainfall, or irrigation water to which the PCU granule is exposed does not significantly alter the rate of release [2]. As long as some soil moisture is present to maintain the osmotic release mechanism, the urea release will continue by this osmotic diffusion process. Whether the PCU granules are completely immersed in water in a paddy rice field, or in moderate-moisture soil in a cotton field, or in a 2 x 2 band placement in high-moisture soil in a no-till corn field, or in an essentially dry soil in a nonirrigated wheat field, the release rate of that PCU will be unchanged by the amount of water present. The driving force for urea diffusion or release is from the inside, pushed out by the concentration of dissolved urea inside the PCU. Indeed, the word osmosis is derived from the Greek “osmos,” meaning “a pushing.”

A soil environment factor that does have an effect on release rate is temperature. At a higher soil temperature, the dissolved urea and water molecules inside the PCU are more thermodynamically activated, which accelerates diffusion and the release rate. As a general rule, for each 18°F (10°C) temperature increase, the rate of release will double. A doubling of release rate means that the time over which the PCU will release urea nitrogen will be reduced by one-half. For example, if a PCU with a given polymer coating thickness has a release duration of four months at 68°F (20°C), that same PCU would release over just two months under steady temperature conditions of 86°F (30°C).

A given PCU in a given soil environment will release urea nitrogen at a fairly steady rate until 50% of the urea from that PCU granule has been released. From that point, the rate of diffusion or release of urea from the PCU will begin to decrease as the internal solution concentration of the polymer-encapsulated urea decreases.

The management of controlled-release nitrogen applications requires recognition that a fairly thinly coated PCU placed in a 2 x 2 band on corn at time of planting in the cool soils of northern Europe will have a longer induction period and a relatively slow release rate until the soils begin to warm. As the soils warm in late spring and early summer, the normal tendency for the PCU release to slow may be more than offset by the accelerating release rate effect of the increasing soil temperature. As a result, the release profile, or dissolution rate (DR) profile, of a POLYON AG PCU will appear similar to the nitrogen uptake profile of a corn plant during its growth cycle. However, it is important for the PCU to be releasing predictably in advance of the nitrogen demand by the crop. Obviously, any PCU nitrogen release that occurs past the demand period of the crop growth cycle will not benefit the crop and may move into the groundwater.

For a fall-planted winter wheat crop, the temperature change is the reverse. Following PCU application at time of planting in the fall, the soils become progressively colder. For this crop, a somewhat heavier, but still thin polymer coating would be used for the PCU. This somewhat thicker polymer coating would
minimize the amount of nitrogen released by the PCU during the time from planting through emergence and early growth until the ground freezes. Both the plant growth and the PCU release essentially shut down during the winter. The PCU release would resume during spring greenup and would continue to release to feed nitrogen during the kernel development and head-filling stage. Application of PCU at time of planting winter wheat may provide the following two functions for the controlled-release urea nitrogen. First, release of urea in the fall would function to improve plant and root growth and tillering, or stand density. Then resumption of release from the PCU during spring warmup would function to increase kernels per head, kernel size, and, perhaps, protein levels in the grain.

The cost of CRN in PCU necessarily will be higher than the cost of nitrogen or other commercial soluble nitrogen fertilizers in the uncoated form. The CRN cost of a PCU is affected significantly by the coating thickness, which is related to the amount or weight percent of the polymer membrane coating applied onto the urea granule to control its release rate. A longer release time requires a slower release rate, which is controlled by increasing the thickness of the RLC polymer membrane. A thicker membrane coating results in a higher weight percentage of polymer and, correspondingly, a lower weight percentage of urea in the PCU formulation, which means also that the nitrogen analysis, or grade, will be lower. Examples of the effect of coating thickness for PCU granules by the RLC process are shown in Table 1.

In a typical application some soluble nitrogen is used along with POLYON, which is a more efficient nitrogen source. The amount of CRN fertilizer used is very important to both the input cost and the crop yield value. Any additional cost per acre/hectare from using POLYON nitrogen generally requires an increase in crop yield with a value of 2 to 3 times the additional input cost to economically justify its use. Of course, this increase in yield value return will be more easily achieved in high-acreage and high-value crops, such as strawberries. However, economic justification can be achieved with POLYON PCU on lower value crops, such as corn or wheat, because the POLYON is a lower cost CRN made possible by the RLC process.

Comparative research data from two on-farm replicated trials on corn and winter wheat are given in Tables 2 and 3 to demonstrate the potential for positive economic yields through the inclusion of CRN from PCU as part of the total nitrogen applied to the crop.

Table 1. Effect of Polymer Coating Thickness on Nitrogen Release Rate

<table>
<thead>
<tr>
<th>Grade POLYON AG</th>
<th>Coating Thickness (µm)</th>
<th>Polymer (%)</th>
<th>Urea (%)</th>
<th>Release Rate—Weeks at 70°F (21°C)</th>
<th>Release Rate—Weeks at 80°F (27°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCU 44.5N</td>
<td>15</td>
<td>3.2</td>
<td>96.8</td>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td>PCU 44.0N</td>
<td>20</td>
<td>4.3</td>
<td>95.7</td>
<td>100</td>
<td>10</td>
</tr>
<tr>
<td>PCU 43.0N</td>
<td>30</td>
<td>6.5</td>
<td>93.5</td>
<td>100</td>
<td>16</td>
</tr>
<tr>
<td>PCU 42.0N</td>
<td>40</td>
<td>8.6</td>
<td>91.4</td>
<td>100</td>
<td>22</td>
</tr>
</tbody>
</table>

3. The reactive layers coating (RLC) technology of Pursell Technologies Inc., with the brand name, POLYON AG PCU, utilizes thickness of the polymer-coating membrane to control rate of release. The Japanese technology, sold in the United States as MEISTER® PCU, utilizes a different release-rate-controlling mechanism, wherein an additive formulated at varying amounts into a fixed thickness polymer coating alters the coating permeability rate.

Table 2. Comparison of Corn (Maize) Yield Data Using POLYON CRN With Urea and Urea Alone

<table>
<thead>
<tr>
<th>N Source</th>
<th>No Till 2x2</th>
<th>Sidedress at V-6a</th>
<th>Total N</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCU 44N</td>
<td>60</td>
<td>0</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Urea 46N</td>
<td>0</td>
<td>90</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>90</td>
<td>150</td>
<td>139</td>
</tr>
<tr>
<td>Urea 46N</td>
<td>60</td>
<td>90</td>
<td>150</td>
<td>116</td>
</tr>
</tbody>
</table>

Comparative treatments from farm field replicated strip plots research in north central Ohio.

a. 50% of the plants with six developed nodes on the main axis.
A number of patents [3] have been issued worldwide on the RLC process and product. The most recent U.S. Patent was issued in 1999. POLYON PCU, which is produced by the RLC process, is made by chemically reacting the polymer to the urea surface, where the coating and the urea become physically joined together to make an extremely tough, durable, controlled-release nitrogen product. The development in the United States of POLYON began in the mid-1980s. It was achieved commercially by Pursell Technologies Inc., Sylacauga, Alabama, U.S.A., with the startup in February 1992, of the first U.S. polymer-coating plant specifically designed for the production of PCU. This breakthrough technology for polymer coating urea became known as the reactive layers coating, or RLC, process because of the method of sequentially applying several different solvent-free liquid coating components in layers onto cascading urea granules in a rotating drum, whereupon the liquids chemically react with the urea granule and with each other to form the final ultra-thin polymer coating. These thinner polymer coatings applied by the RLC process have a pronounced effect on keeping the PCU cost low compared with other PCU process technologies. Further, since it is a solvent-free polymer coating process, considerable advantages and flexibilities in the coating processing operation are realized. The process has continued to be modified and improved since its commercial introduction in 1992.

The POLYON Polymer-Coated Urea Process

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Table 3. Comparison of Wheat Yield Data Using POLYON CRN With Urea and Urea-Ammonium Nitrate (UAN) Solution Without POLYON

<table>
<thead>
<tr>
<th>N Source</th>
<th>Conventional Till Incorporation at Planting</th>
<th>Spring Topdress February</th>
<th>Spring Topdress March</th>
<th>Total N</th>
<th>Yield Heads/ft²</th>
<th>Kernels/Head</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCU 43.5N</td>
<td>15 (lb N/acre)</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>95</td>
<td>29</td>
</tr>
<tr>
<td>UAN 32N</td>
<td>0</td>
<td>40</td>
<td>40</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urea 46N</td>
<td>15 (lb N/acre)</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>95</td>
<td>32</td>
</tr>
<tr>
<td>UAN 32N</td>
<td>0</td>
<td>40</td>
<td>40</td>
<td>80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comparative treatments from farm field replicated plot research in eastern Virginia, administered by Virginia Tech Cooperative Extension. 1997/98.

The potential markets for POLYON PCU

The task is to establish significant POLYON research with the crops and soils in many countries. For example, on the northeastern coast of Australia, an intensive 3-year research study on sugarcane is underway. Crop-ping systems of this ratoon crop coupled with excessive nitrogen fertilizer applications onto crop residues result in a significant reduction in plant uptake of the applied nitrogen. It is generally believed that only about 20% of the applied nitrogen is utilized by the crop. Volatilization, leaching into the groundwater, and run-off into the ocean account for much of the nitrogen inefficiency (loss). If left unchecked, one concern is that nitrate pollution will cause damage to the Great Barrier Reef. It is a responsibility of the fertilizer industry to not let this happen, and POLYON can play an important role in contributing to the solution to this problem.

If the POLYON research in crops is successful, then the development of markets for POLYON will justify the construction of licensed POLYON coating plants to supply POLYON locally. The goal is to develop a market demand for the POLYON that will justify building polymer coating plants by licensing the technology to agricultural business leaders in countries around the world. The expertise and the capability to build low-cost plants to produce POLYON exist today with our firm.

The world consumption of nitrogen fertilizer is at a record level of about 85 million mt of
nitrogen annually of which approximately 50% is urea nitrogen. Worldwide consumption of controlled-release nitrogen is estimated to be only about 0.25% of the total world nitrogen use, and nearly all of the CRN use is for nonagricultural applications. The potential for market growth of CRN in commercial agricultural cropping systems is huge. The environmental and economic benefits of enhanced-efficiency POLYON controlled-release nitrogen fertilizer promise to make POLYON the fertilizer of the future.

**Conclusion**

There are environmental benefits derived by using POLYON PCU fertilizer. Replacing soluble nitrogen with CRN immediately reduces risk of nitrates leaching into the groundwater. Further, POLYON enhances the nitrogen uptake efficiency by the plant, which further reduces the potential for nitrates going into the groundwater. Nitrogen that is taken up by the plant is not available to be leached as nitrate.

There are economic benefits associated with the use of POLYON PCU fertilizer. Increased nitrogen uptake by the plant increases the potential for increased plant growth and crop yield, which will economically benefit the farmer. Another economic benefit is in production of PCU by the RLC process. POLYON PCU has a lower production cost, which results in a lower cost CRN fertilizer than can be produced by other PCU technologies.

POLYON can be tailored to commercial cropping systems. The programmable, precision release of nitrogen, which is governed by the thickness of ultrathin coating encapsulating the urea granule, makes POLYON PCU fertilizer an applicable CRN source in many cropping systems. Although not all crops nor all soils nor all climates will justify the use of CRN, certainly a significant percentage of crops and soils will benefit from the use of POLYON PCU.

**References**

Impact of Farming Practices and Diet on Fertilizer Products and Use

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Introduction

The globalization of agriculture is forcing producers to seek lower unit costs of production in order to compete with a broadening base of producers around the world. Some strategies being used to achieve profitability are more efficient use of fertilizer, increasing farm size, switching to reduced tillage, and growing higher value crops. In addition, environmental concerns are prompting a reconsideration of input levels, and biotechnology is showing early signs of having a significant impact on management strategies in the future. In underdeveloped countries basic dietary needs intensify the drive toward greater use of basic, or common, fertilizer products. However, consumers in these underdeveloped countries are gradually becoming more mindful of diet quality (as opposed to quantity). This has the potential to affect the use of traditional as well as nontraditional fertilizer products.

General Needs for Improved Fertilizer Practices—China Versus the United States

The world’s two largest users of commercial fertilizers are China and the United States with Europe following closely behind (Figure 1). These two countries (China and the United States) provide an interesting contrast in viewing agricultural development and future fertilizer needs.

Developing countries such as China will be responsible for increases in fertilizer sales in the future (Figure 2).

The United States is generally considered, somewhat mistakenly so, a mature market. China’s average annual increase of nutrient consumption is about 1.6 million mt. Generally speaking, China could now be considered to be at the point of development that some developed countries were in the first half of this century. Currently, the majority of farming and agricultural activities in China are under the family responsibility system. These are small-scale operations with farmers who would benefit greatly from agricultural training. There is little

![Figure 1. World Crop Nutrient Demand.](image-url)
infrastructure in place for education and information to advance agronomic knowledge about fertilizer products and practices. In comparison, the United States had established early in the century a university extension service to help disseminate basic knowledge of agricultural practices, including fertilizer use, to producers. Today, China is in need of such an information infrastructure. In addition, fertilizer production, distribution, transportation, utilization, and services are separate responsibilities of various government agencies. As their development continues, more of the common fertilizer materials, such as urea, will be used in a shift away from ammonium bicarbonate, which is in wide use (48% of all nitrogen in 1996) and not suitable for many of their soils and tillage practices. Efficiency of use is low for such sources (ammonium bicarbonate contains 17% N). Nitrogen recovery in cropping systems is also low in China and is estimated to be only 30%, whereas in North America it is 50%. In terms of fertilizer products, emphasis in China needs to be on procurement and promotion of the common sources of fertilizers and the basic principles of their proper agronomic use.

**Soil Testing Indicators—China and the United States**

Both countries have a need for further improvement in the balanced nutrition of crops. Soil testing surveys show that both countries have significant room for improvement in balancing fertilizer inputs (Figure 3 and Table 1).

The United States, despite a history of a strong overall economy, has not always enjoyed a strong agricultural economy. Consequently, large areas of P- and K-deficient soils can still be found across the country. Poor commodity prices, modest acceptance of soil testing, and grower resistance to change are some of the reasons why nutrient limitations still exist in the United States despite significant educational efforts. As mentioned earlier, the United States is considered a mature fertilizer market; however, the limitations shown in Figure 3 indicate that increased sales could be realized.

China, on the other hand, has even greater areas of deficient soils. There is no infrastructure of testing laboratories for farmers to use. Large increases in yield and profits could easily be realized on such soils. Soil testing and recommendation programs that consider the importance of all essential nutrients have not been developed, and most of the farmers in China still apply their fertilizers without a scientific basis, either according to their own experience or following the practices of their neighbors. Consequently, unbalanced fertilization and overuse of N have caused low fertilizer-N use efficiency and have led to...
Table 1. Opportunities for Increased Production in China

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>% of Total Arable Land</th>
<th>Nutrient</th>
<th>% of Total Arable Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>98</td>
<td>Zn</td>
<td>51</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>90</td>
<td>B</td>
<td>34</td>
</tr>
<tr>
<td>K₂O</td>
<td>60</td>
<td>S</td>
<td>28</td>
</tr>
</tbody>
</table>

Source: Potash & Phosphate Institute (PPI).

environmental pollution in some areas.

Diet Awareness

Caloric intake in China is not high, but certainly is not as critical as it is in parts of South America, southern Africa, and India (Figure 4). These parts of the world are in need of greater amounts of basic foodstuffs to meet minimum caloric and protein needs. These countries would obviously benefit simply from the use of greater amounts of common types of fertilizer used in developed countries. In 1990, the Food and Agriculture Organization of the United Nations (FAO) estimated that 786 million people in the world were chronically undernourished, including 530 million in Asia and 170 million in Africa.

In contrast, some people in developed countries consume excess calories but still suffer from poor nutrition because the processed or "convenience" food they eat does not contain minimum daily requirements. A former U.S. Surgeon General was quoted as saying that the typical grocery basket did not contain the necessary nutrients for good health. The Journal of the American Medical Association recently recognized that the "era of nutrient supplementation to promote health and reduce illness is here to stay." To increase public awareness of the importance of calcium intake, the United States Food and Drug Administration authorized food manufacturers in 1993 to make health claims on food labels. These changes clearly signal an increasing awareness among the public of the poor quality of foods in their diet. Unfortunately, it is only awareness. Surveys of the American public indicate a high concern for diet and awareness of the potential impact on health but also widespread ignorance as to the corrective action needed. A large part of the problem is simply education: physicians in the United States receive little or no training in nutrition, and public and private school systems also spend essentially no time educating their students on the topic. Those engaged in ag-

Figure 4. Daily Calories Per Capita.
riculture will have to make rather significant marketing efforts to heighten the visibility of quality in the commodities it produces. As that is achieved, those who provide fertilizer products and practices that provide higher quality foodstuff can be financially compensated for their efforts.

**Shifts in Food Base and Fertilizer Inputs**

Economic progress allows more of a population to move from a rice- or sorghum-based diet to one with wheat as a base grain. With further progress, more vegetables and meat will be included with the wheat. Fertilizer sources, rates, and practices increase in sophistication as economies reflect this change in diet. Together with processed and convenience foods in an “advanced” diet (which may very well be a nutritionally inferior diet) are smaller markets, such as the organic growers (which are experiencing double-digit growth). Some of our retail fertilizer outlets have told me personally that they are happy to serve the needs of these growers, despite the fact that they are not their conventional customers. Why? Because the dollar input levels per acre or hectare are large. These growers can be significant spenders. As the dollar value of their crops increases, so will the margins realized by those who serve their needs. Similarly, contract farming for specific traits in crops, including genetically engineered crops, will observe a similar trend. The value of the crop now becomes an important consideration in formulating the fertilizer recommendation for those fields. The risk of being on the low side of a recommendation becomes too great. It becomes an easy decision to apply higher levels to ensure an adequate supply of nutrients. In addition to higher total amounts of typical N, P, or K fertilizers, special products or programs, such as slow-release fertilizers or full-spectrum fertility programs (for example, macronutrients and micronutrients), become a more affordable possibility in the mind of the producer. Sometimes heard from “organic” growers is that soils in traditional agriculture are routinely found depleted of micronutrients compared with levels found in similar virgin soils. If this is the case, traditional agriculture should take the opportunity to sell greater amounts of micronutrients on traditionally farmed soils and not rely solely on soil test critical values, as espoused by the university recommendation systems, which place emphasis on yield and give little, if any, thought to quality characteristics.

**Reduced Tillage**

Reduced-tillage systems have the potential to reduce unit costs of production. In 10 years no-till agriculture has grown from 15 to 110 million acres (6 to 45 million ha) worldwide. Some 58% of this adoption is outside the United States, with Canada, Brazil, and Argentina leading the way (Figure 5).

Declining government support payments in the United States, Canada, and Australia are prompting farmers in those countries to adopt reduced tillage to reduce costs. No-till in soybeans has reduced the cost of production by US $27/acre (US $67/ha) in Argentina and US $14/acre (US $35/ha) in the United States. The Argentine farmer can save more per hectare partially because he saves more on fertilizer. New or nearly virgin soils require less fertilizer than soils farmed for a long time. Eventually, the Argentine farmer will see his yields decline, and fertilizer inputs will have to increase to maintain productivity. Another recent development has been the response of rice to no-till in Southeast Asia (Figure 6). Smallholder farmers in Indonesia are realizing a 25% saving in labor, 65% saving in land preparation cost, and 28% saving in irrigation water per cropping cycle, while saving 2 to 3 weeks for land preparation. These savings will help move production...
from the current average of 1.4 crops/year to a potential of 3 crops/year. Similar results are being observed in the Philippines, Thailand, and India. These developments will help these countries reach the goal of self-sufficiency and reduce the need for imports from others, such as the United States.

These increases in productivity will increase demand for fertilizer used in reduced-tillage systems. With regard to N fertilizers, urease inhibitors for urea and nitrification inhibitors for ammonium-based fertilizers will have a greater potential for sales. However, increasing the sales of these products requires strong educational and promotional programs. For example, growers, when considering the use of such products, very often view the incremental cost of the specialty product as offering no better potential return than would purchasing an equivalent amount of additional N. Although there are significant flaws associated with this logic, one must still convince them to change; this is not always easy. Education of dealers and their growers is one of the keys to creating a market for products and services.

**Education and Information to Create Markets**

One of the new efforts of the Cenex/Land O'Lakes Agronomy Company involves educating fertilizer retail dealers about the use of micronutrients. As mentioned earlier, soil-testing surveys have shown the legitimate potential for sales. However, dealers and their farmer customers must be made aware of these data. To correct this problem, an extensive educational effort was initiated by Cenex/Land O'Lakes this past winter in seven upper Midwest states of the United States. Thirteen training locations were made available to dealers in our system. The classes were free of charge and conducted over the course of 1 day. Emphasis was placed on showing micronutrient need in their locality for their most common crops and soils. Extensive discussion also focused on nutrient source and placement. Probability of response and prioritizing macronutrient and micronutrient input dollars were also covered. An outline for a field-testing program was presented, and participants were encouraged to actively engage in field demonstrations to demonstrate to their producers (customers) the benefits of micronutrients. Finally, during the day, a marketing staff representative outlined product pricing, margin returns, supply, and distribution of the company’s micronutrient products.

Over 350 dealers attended the school. Approximately 50 dealers agreed to initiate field trials the first year in six states. Data obtained from these trials will be used in next year’s follow-up training. The data will help clarify market needs for micronutrients as well as the effectiveness of our proprietary sources of micronutrients. In addition, field trials are used to advocate the use of yield monitors to measure yields—establishing cause and effect, locally. With advancements in new technologies, such as yield monitors, there is a tremendous opportunity to educate people about the direct consequences of using a particular product or practice. They can quantify the effect of a product or practice on their crops. We could provide this information before, but it is now getting much easier to do so.

**New Technologies**

Good recordkeeping is a key to successful management. Many new technologies exist to facilitate the gathering of production data and recordkeeping. Database software provides state-of-the-art recordkeeping. Global positioning systems (GPS) allow collected data to be geographically referenced. Spreadsheets and geographic information systems (GIS) are powerful tools that can be used for spatial analysis of geographically referenced data. This technology is underutilized in China and is being more extensively used in
many parts of Europe and North America. As alluded to above, these technologies are being used in our efforts to position micronutrients. What we learn will undoubtedly assist us as we train our field agronomy employees (retail dealers) in future related programs.

Also in the realm of new technology is biotechnology. Although not popular everywhere, consumer demand and desire and a favorable regulatory environment in the United States are fueling the excitement surrounding biotechnology. New surveys find consumers strongly in favor of the potential benefits. One-third of Americans surveyed reported that they are aware that there are products in the supermarket produced through biotechnology. A new question posed in 1999 asked about the benefits of producing cooking oil with reduced saturated fat. Over half of Americans surveyed say that this would positively affect their purchasing decision. In Argentina, 5.5 million of 7 million ha of that country's soybean crop is transgenic, incorporating certain genetic alteration. Examples of genetically altered crops are those with additional vitamins, altered fat profiles, and special medicinal traits. These products could potentially be marketed as whole foods, processed foods, or in the traditional medicinal format as pills. Specific examples are oranges that replace daily multivitamins or soybeans containing insulin for the treatment of diabetes. As mentioned earlier, these types of high-value crops will be well maintained agronomically because higher input levels are easily justified.

**Conclusion**

One of the brightest points to be made about the future of fertilizer use is that soil test survey data show significant needs in undeveloped as well as developed countries. Even in the United States, where there has been a strong history of fertilizer use, there is room for improvement in the management and overall use of fertilizers. This applies to both macronutrients and micronutrients. Generally, obstacles to achieving wider and wiser use are the perception that a need does not exist and a poor understanding of economic return. The result is inaction. Effective information/education programs can help bring about change.

Reduced-tillage systems can help reduce labor, fuel, and machinery costs. Reduced tillage on newly cleared lands in South America requires low fertilizer inputs. Eventually, these inputs will need to be increased as natural fertility diminishes. Some specialty products can enhance N management in reduced tillage. Higher P and K levels are often needed in less tilled soils in North America because of cooler, wetter conditions. The area currently under reduced tillage is relatively low but is increasing.

Apart from meeting basic caloric and protein needs, the dietary impact on fertilizer products and use is relatively minor. However, there are many signs that consumers in developed countries are becoming more aware of and concerned about the impact of diet on health and longevity of human life. Development of products and their use to enhance crop quality will become more important as consumers increase their knowledge about the quality of the human diet. Research, educational, and marketing programs will be needed to identify and increase the market for such products.
International Workshop
Current Environmental Issues of Fertilizer Production
June 7-9, 1999

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