Fertilizer Dealer Handbook

An International Center for Soil Fertility and Agricultural Development

Products, Storage, and Handling
Fertilizer Dealer Handbook
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Foreword

IFDC was established in 1974 as a public, international, nonprofit organization to address global food security challenges through improved use of fertilizers and related technologies. Since inception, IFDC programs have been sharply focused on the achievement of enduring solutions to soil fertility management.

IFDC is a unique international organization because it works with the full spectrum of agricultural stakeholders including governments, private sector input businesses, and farming communities to build human capacity that simulates better use of agricultural inputs needed to improve farm productivity.

One of the main focus areas of IFDC is to increase agricultural production through the creation, development, and nurturing of a private sector that will undertake the various functions necessary to enhance agricultural productivity. This includes training private sector input dealers on the various types of fertilizers, their properties, and efficient use. This will enable the fertilizer dealer to properly store and handle his fertilizers as well as recommend to his farmer customers the best fertilizer types and use for his crops. This handbook is designed to complement that training.

Amit H. Roy
President and Chief Executive Officer
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## Acronyms and Abbreviations

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<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AN</td>
<td>Ammonium nitrate</td>
</tr>
<tr>
<td>AS</td>
<td>Ammonium sulfate</td>
</tr>
<tr>
<td>B</td>
<td>Boron</td>
</tr>
<tr>
<td>B₂O₃</td>
<td>Boron oxide or boric oxide</td>
</tr>
<tr>
<td>Ca</td>
<td>Calcium</td>
</tr>
<tr>
<td>CAN</td>
<td>Calcium ammonium nitrate</td>
</tr>
<tr>
<td>CaO</td>
<td>Calcium oxide</td>
</tr>
<tr>
<td>Cl</td>
<td>Chloride</td>
</tr>
<tr>
<td>CRF</td>
<td>Capital Recovery Factor</td>
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<td>CRH</td>
<td>Critical relative humidity</td>
</tr>
<tr>
<td>Cu</td>
<td>Copper</td>
</tr>
<tr>
<td>DAP</td>
<td>Diammonium phosphate</td>
</tr>
<tr>
<td>Fe</td>
<td>Iron</td>
</tr>
<tr>
<td>HDPE</td>
<td>High-density polyethylene</td>
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<tr>
<td>K</td>
<td>Potassium</td>
</tr>
<tr>
<td>KCl</td>
<td>Potassium chloride</td>
</tr>
<tr>
<td>K₂O</td>
<td>Potassium oxide</td>
</tr>
<tr>
<td>LLDPE</td>
<td>Linear low-density polyethylene</td>
</tr>
<tr>
<td>LDPE</td>
<td>Low-density polyethylene</td>
</tr>
<tr>
<td>MAP</td>
<td>Monoammonium phosphate</td>
</tr>
<tr>
<td>Mg</td>
<td>Magnesium</td>
</tr>
<tr>
<td>MgO</td>
<td>Magnesium oxide</td>
</tr>
<tr>
<td>Mn</td>
<td>Manganese</td>
</tr>
<tr>
<td>Mo</td>
<td>Molybdenum</td>
</tr>
<tr>
<td>MOP</td>
<td>Muriate of potash, potash, or potassium chloride</td>
</tr>
<tr>
<td>MSDS</td>
<td>Material Safety Data Sheets</td>
</tr>
<tr>
<td>N</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>P</td>
<td>Phosphorus</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>Phosphorus pentoxide</td>
</tr>
<tr>
<td>RC</td>
<td>Reinforced concrete</td>
</tr>
<tr>
<td>S</td>
<td>Sulfur</td>
</tr>
<tr>
<td>SO₃</td>
<td>Sulfur trioxide</td>
</tr>
<tr>
<td>SOP</td>
<td>Sulfate of potash or potassium sulfate</td>
</tr>
<tr>
<td>SSP</td>
<td>Single superphosphate</td>
</tr>
<tr>
<td>TSP</td>
<td>Triple superphosphate</td>
</tr>
<tr>
<td>UV</td>
<td>Ultra violet</td>
</tr>
<tr>
<td>WPP</td>
<td>Woven polypropylene</td>
</tr>
<tr>
<td>Zn</td>
<td>Zinc</td>
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</table>
Fertilizer Dealer Handbook  
*Products, Storage, and Handling*

1. Introduction

As a fertilizer dealer, you should be knowledgeable about the chemical and physical characteristics of the fertilizers that you sell. This knowledge can be used not only to benefit your customers but also to help you do a good job of properly storing and handling your fertilizer stock.

The purpose of this handbook is to provide you, the fertilizer dealer, with a source of information on (1) plant nutrients and nutrient forms, (2) common and useful fertilizer terms and definitions, (3) important storage and handling properties of fertilizers, (4) common fertilizer products and product descriptions, (5) labels, (6) bag types and sizes, (7) fertilizer storage facility characteristics, (8) inventory control and operation, (9) good housekeeping guidelines, and (10) safety and security considerations.

2. Plant Nutrients

Classification

Chemical elements that are essential for the proper development and growth of plants are typically referred to as plant nutrients. Plant nutrients typically recognized as being necessary for plant development and growth total 16, three (carbon, hydrogen, and oxygen) that are supplied by air and water.

The remaining 13 plant nutrients are typically supplied through the soil from soil reserves or by the application of fertilizer materials. These 13 plant nutrients are commonly categorized into macronutrients (large amounts usually required) and micronutrients (small amounts usually required). Macronutrients are typically divided into primary nutrients (nitrogen, phosphorus, and potassium) and secondary nutrients (calcium, magnesium, and sulfur). The micronutrients (also referred to as trace elements) are boron, chlorine, copper, iron, manganese, molybdenum, and zinc.

Expression

Most countries express the quantities or percentages of the primary nutrients in fertilizer materials as nitrogen (N), phosphorus pentoxide (P₂O₅), and potassium oxide (K₂O). A few countries express the quantities or percentages of phosphorus and potassium in the elemental forms (P and K). Secondary nutrients and micronutrients in fertilizer materials are usually expressed on an elemental basis (Ca, Mg, S, B, Cl, Cu, Fe, Mn, Mo, and Zn), although some countries may use the oxide form for calcium (CaO), magnesium (MgO), sulfur (SO₃), and boron (B₂O₃). Conversion factors for those plant nutrients that may be expressed in the elemental or oxide form, depending on the country, are shown in Table 1.

<table>
<thead>
<tr>
<th>From Oxide to Elemental</th>
<th>From Elemental to Oxide</th>
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<tbody>
<tr>
<td><strong>From Oxide to Elemental</strong></td>
<td><strong>From Elemental to Oxide</strong></td>
</tr>
<tr>
<td>P₂O₅</td>
<td>X</td>
</tr>
<tr>
<td>K₂O</td>
<td>X</td>
</tr>
<tr>
<td>CaO</td>
<td>X</td>
</tr>
<tr>
<td>MgO</td>
<td>X</td>
</tr>
<tr>
<td>SO₃</td>
<td>X</td>
</tr>
<tr>
<td>B₂O₃</td>
<td>X</td>
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<tr>
<td>P</td>
<td>X</td>
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<tr>
<td>K</td>
<td>X</td>
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<tr>
<td>Ca</td>
<td>X</td>
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<tr>
<td>Mg</td>
<td>X</td>
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<td>S</td>
<td>X</td>
</tr>
<tr>
<td>B</td>
<td>X</td>
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</table>
Nutrient Availability
A commercial fertilizer is a material containing at least one of the plant nutrients in a form assimilable or “available” to plants in known amounts. Generally, a plant nutrient is taken up by plant roots or foliage in the form of a solution in water. Plant nutrients form many different chemical compounds having varying degrees of solubility in water.

Thus, it would seem that water solubility should provide a simple conclusive measure of the availability to plants. In most cases such as most commercial nitrogen and potassium fertilizers, water solubility is, indeed, a sufficient measure of nutrient availability to plants.

However, for some fertilizer types, nutrient availability may be expressed based on their solubility in another medium or reagent other than water. For example, the availability of phosphate in most commercial phosphate fertilizers is expressed based on solubility in dilute chemical solutions. Therefore, most countries specify some degree of solubility of the nutrient content in water or dilute chemical solutions depending on the fertilizer product.

3. Types of Fertilizers
Fertilizers are materials that serve as carriers for plant nutrients. Fertilizers are typically identified using various classification schemes including the (1) origin of the raw materials used to produce them, (2) number of plant nutrients present, (3) production process, and/or (4) physical form of the material. Following are some terms used to classify fertilizer types.

Inorganic Fertilizers are fertilizer materials in which the declared nutrients are in the form of inorganic salts obtained by extraction and/or by physical and/or chemical industrial processes. These materials are also often referred to as mineral or chemical fertilizers. Although containing carbon, urea is typically classified in this category.

Organic Fertilizers are carbonaceous materials derived from non-synthetic organic material mainly of vegetable and/or organic origin.

Straight Fertilizers are fertilizers that contain only one primary plant nutrient. Examples are urea, ammonium nitrate, ammonium sulfate, triple superphosphate, single superphosphate, and potassium chloride (potash).

Multinutrient Fertilizers are fertilizers having a declarable content of at least two of the primary plant nutrients obtained from chemical reaction(s) or by blending or both. These materials are also often referred to as compound fertilizers. Examples are diammonium phosphate, monoammonium phosphate, and NPKs produced by chemical reaction and granulation or by physical blending.

Complex Fertilizers are fertilizers manufactured through processes involving chemical reaction between the constituents containing the plant nutrients. Examples are diammonium phosphate and nitrophosphate NPKs.

Blended Fertilizers are fertilizers manufactured through the process of dry mixing without chemical reactions. An example would be physically mixing granular urea, granular diammonium phosphate, and granular potash into a predetermined ratio and nutrient content.

Slow Release Fertilizers are fertilizers whose nutrients are present as a chemical compound or in a physical state such that their availability to plants is spread over time. Other similar terms are controlled-release, coated, stabilized, and inhibitor. Examples are polymer-coated urea and urease inhibitors.
Granular Fertilizer is a term used to define a fertilizer that is produced by agglomeration or accretion through chemical and/or physical processes. Examples are granular urea and granular diammonium phosphate. This term is also used to define fertilizer material that is screened to a specified particle size range.

Figure 1. Granular Diammonium Phosphate

Compacted Fertilizer is a term used to define a fertilizer that is produced by compression of powdered and/or semi-granular fertilizers under high pressure into a predetermined particle size range. Some potash products are typical compacted materials.

Figure 2. Compacted Muriate of Potash

Prilled Fertilizer is a term used to define a fertilizer that is produced by solidification of droplets of fertilizer falling from a prilling tower. Examples are prilled urea and prilled ammonium nitrate.

Figure 3. Urea Prills

Powdered Fertilizer is a term used to define a fertilizer in the form of very fine particles, usually with some upper size limit but no lower limit. Other similar terms are run-of-pile and standard. An example of a fertilizer available as powdered or run-of-pile is single superphosphate. An example of a fertilizer available in standard form is ammonium sulfate.

Figure 4. Run-of-Pile (Powdered) Single Superphosphate
4. Terms and Definitions

The following terms and definitions are commonly used in the fertilizer industry and may be useful to you in dealing with your customers as well as your fertilizer suppliers.

**Soil Conditioner** is a material added to soils, the main function of which is to improve their physical and/or chemical properties and/or their biological activity.

**Liming Materials** are soil conditioners that are usually calcium and/or magnesium carbonates and are used for the purpose of neutralizing soil acidity.

**Fertilizer Conditioner** is a substance added to a fertilizer to improve its physical condition or prevent caking. The conditioning agent may be applied as a coating or incorporated into the product.

**Filler** is a substance without any declarable fertilizer nutrient content that is added to a fertilizer to adjust the fertilizer grade.

**Heavy Metals** are metallic elements that, at critical concentrations, can be toxic to plants, animals, and humans. Although uncommon, heavy metals such as cadmium, mercury, chromium, lead, nickel, and vanadium may be present in critical levels in some phosphate fertilizers, sewage sludge, animal manures, and micronutrient sources.

**Grade** refers to a series of numbers, separated by dashes, that represents the primary nutrient content of a fertilizer expressed in the order nitrogen-phosphorus-potassium. For example, a fertilizer with 10% each of nitrogen (as N), phosphorus (as P₂O₅), and potassium (as K₂O) would be a 10-10-10 grade. The grade is usually clearly indicated at the top of the fertilizer bag.

**Guaranteed Analysis** refers to the quantitative and/or qualitative characteristics of a fertilizer material, which are guaranteed on the bag/container or invoice received with a shipment of fertilizer. Other similar terms are *guarantee of composition, formula, and declarable content*.

**Net Weight** means the weight appearing on bags/containers of fertilizer and refers to the actual weight of the fertilizer in the bag/container.

**Brand** is a term, design, or trademark used by a fertilizer company in connection with one or several grades of fertilizer.

**Label** refers to the display of all written, printed, or graphic material upon the immediate bag/container. In a legal context, it can also mean any statement accompanying a fertilizer or advertisements, brochures, posters, television, radio, or internet announcements used in promoting the sale of fertilizer.

**Percentage** means the percentage by weight. For example, a 50-kilogram bag of urea containing 46% nitrogen would contain 23 kilograms of nitrogen (50 kilograms x 0.46).

**Plant Nutrient Ratio** is the ratio of two or more primary nutrient percentages to another. For example, a 5-10-15 grade has a 1-2-3 ratio and a 20-10-0 grade has a 2-1-0 ratio.

**Misbranded Fertilizer** is a fertilizer that has been falsely labeled or the label is misleading in any manner.

**Adulterated Fertilizer** is a fertilizer that (1) contains any deleterious or harmful ingredient in a sufficient amount to render it injurious to beneficial plant
life, animals, humans, aquatic life, soil, or water when applied in accordance with directions for use; and/or (2) its composition falls below that which is guaranteed on the label.

**Short Weight Fertilizer** is any fertilizer that is short in weight by any amount below the net weight guaranteed.

**Nutrient Deficient Fertilizer** is any fertilizer where the nutrient content, by analysis, falls below the guaranteed analysis stated on the container, bag, or invoice accompanying the fertilizer.

**Potash** is a name often used rather than the more scientific term, potassium chloride.

**Chloride-Free Fertilizer** is a fertilizer containing less than some specified amount of chlorine. Because the usual source of chlorine in fertilizer is potassium chloride (potash), the term usually means a fertilizer containing potassium from some other source such as potassium sulfate or potassium nitrate. Low-chlorine fertilizers may be preferred for agronomic reasons.

**Liquid Fertilizers** or **Fluid Fertilizers** are general terms used for fertilizers wholly or partially in solution that require handling as a liquid.

**Acronyms** or **Abbreviations** are often used to identify the more common fertilizers. The following list indicates those acronyms most commonly encountered:

1. Ammonium nitrate (AN).
2. Ammonium sulfate (AS).
3. Calcium ammonium nitrate (CAN).
4. Diammonium phosphate (DAP).
5. Monoammonium phosphate (MAP).
6. Triple superphosphate (TSP).
7. Single superphosphate (SSP).
8. Potassium chloride or muriate of potash (MOP).
9. Potassium sulfate or sulfate of potash (SOP).

**5. Properties of Fertilizers**

Physical quality is an important criterion used by many consumers in selecting a particular fertilizer. The acceptability of a fertilizer in the marketplace depends not only on its nutrient content but also on its physical quality. Therefore, in the fertilizer distribution and dealer network, it is important that fertilizers have and maintain a certain level of physical quality. Following are some of the more important physical characteristics to a fertilizer dealer.

**Particle Size Distribution** of fertilizers is defined as the particle diameter range of the material. The particle size distribution of fertilizers may affect agronomic response as well as storage, handling, blending, and application properties.

Some fertilizers, such as direct application phosphate rock and micronutrients in the oxide form, are of low water solubility and must have a very small particle size to ensure agronomic response. Powdered micronutrient oxides are often granulated with a water-soluble binder that reduces its dustiness but, once applied to the soil, breaks down into their original powder form, thus being available to the plant.

Fertilizers that are of granular size (1-3, 2-4, 3-5 millimeters) generally have better storage, handling, and application properties than powder size fertilizers (less than 1.0 millimeter). They are usually less dusty, less likely to cake (form lumps), and do not absorb moisture as quickly.

As described above, a blended fertilizer is produced by dry mixing materials such as granular urea, granular diammonium phosphate, and granular potash into a predetermined ratio and nutrient content. It is extremely important that the fertilizer materials mixed in a blend have particle size distributions that are matched as closely as possible. This is commonly referred to as **physical compatibility**, and refers to the ability of two or more materials to remain thoroughly mixed during handling, storage, and application. Particle size distributions of blend materials are often expressed as their median particle size, referred to as the Size Guide Number or SGN.

**Moisture Content** when specified in fertilizers typically refers to the free water in the product. The amount of free water remaining in the fertilizer after manufacture or absorbed during storage has a huge impact on a fertilizer’s tendency to cake (form lumps). The amount
of free water acceptable in a fertilizer depends on the makeup of that fertilizer; primarily whether the material is in a crystalline or amorphous state or somewhere in between. Typical moisture contents of the more common fertilizer materials are given in the next section of this handbook.

**Free Acidity** is the amount of free acid remaining in fertilizer products where an acid is used in the production process. Products with excess levels of free acid (1) are more hygroscopic than the same product acid-free, (2) increase the tendency of the material to cake, and (3) will increase the acidity of the soil. Products such as ammonium sulfate and single superphosphate, made using sulfuric acid, are more likely to have free acid and thus exhibit these characteristics.

**Bulk Density** is the mass per unit volume of a fertilizer and is a measure of the density of the material, its porosity, and the voids between the particles of the material. For the fertilizer dealer, bulk density is of interest in bag sizing and when considering the capacity of storage spaces and transport vehicles.

Less dense materials such as urea will require a larger bag than more dense materials like potassium chloride. Additionally, you can get more of a denser material in a given storage space than a less dense material.

**Angle of Repose** is the angle with the horizontal at which a fertilizer will stand when poured or dropped into a pile from a fixed overhead point. Knowing the angle of repose of a fertilizer material is essential when determining the capacity of a bulk storage building or bin.

The angle of repose of fertilizers is influenced mostly by particle shape, size, and surface texture. Angle of repose values for fertilizers normally range from about 25° to about 40°. Spherical products, such as prilled urea, usually have lower angle of repose values (<30°). Irregularly shaped products, such as granular potassium chloride, usually have higher angle of repose values (>35°).

**Particle Hardness**, or mechanical strength, of a fertilizer particle is influenced by its chemical composition, method of production, particle porosity, particle shape, surface crystals, and moisture content. Fertilizers should be strong enough to withstand normal handling and storage without significant fracturing of particles and creation of excessive dust.

A fertilizer particle can be subjected to static and/or dynamic mechanical stresses. Static stress results from pressures exerted on particles at the bottom of a bulk pile or stack of bags. Dynamic stress results from abrasion (creation of dusts and fines) or fracturing of particles as a result of particle-to-particle and particle-to-equipment contact during handling.

A “finger test” is a reasonably good, simple field method for evaluating the mechanical strength of fertilizer particles. In this test, a particle/granule that can be crushed between the thumb and forefinger can be classified as “soft/weak.” If it is not classified as soft/weak, but can be crushed between the forefinger and a hard surface, it can be regarded as being of “medium hardness.” If it remains intact when subjected to pressure by the forefinger against a hard surface, it can be classified as “hard/strong.”

**Dustiness** can be a problem with some fertilizers. Excessive dust can result in significant losses during handling, resulting in lost revenue. It can also possibly create environmental problems as well as expose employees to unhealthy levels of dust. Although there are some sources of granular and prilled fertilizer that tend to be dusty, most of the fertilizers considered to be excessively dusty are the powdered, run-of-pile, standard, and crystalline forms of fertilizer.

**Hygroscopicity** is defined as the moisture absorption properties of a fertilizer at specified conditions of relative humidity, ambient temperature, and exposure time. Most fertilizers are hygroscopic to some extent because of their normally high water solubility. The more hygroscopic a fertilizer is, the more problems you can expect during storage and handling. Characteristics of a fertilizer that can influence its degree of hygroscopicity are the chemical composition, moisture content, particle structure, porosity, and particle surface area.
The critical relative humidity (CRH), while not the sole indicator, can give you a good idea of the hygroscopicity of a fertilizer. CRH is the relative humidity of the atmosphere (at a certain temperature) at which a material begins to absorb moisture from the air and below which it will not absorb atmospheric moisture. Figure 6 below shows the CRH of fertilizer materials and their mixtures.

You can see that mixtures of fertilizers always have lower CRH values than the individual ingredients of the mixture. Additionally, it should be pointed out that some fertilizers with similar CRH values may behave much differently when exposed to humidity above their CRH. This is primarily due to the differences in their structural makeup and chemical composition.

Caking is the formation of a solid mass or lumps of fertilizer from individual particles. Caking can be light (commonly referred to as bag set); the lumps break easily back into original individual particles with normal handling. Conversely, caking can be extremely severe, forming a solid mass that can no longer be broken back down into its original particles. Caking can cause many handling and application problems and is considered by most fertilizer producers to be the single biggest physical quality problem in fertilizers.

Characteristics of a fertilizer, which can have an impact on its tendency to cake, are moisture content, product temperature, particle size, particle hardness, presence (or absence) of a fertilizer conditioner (anti-caking agent), and chemical composition. External factors which can influence whether a fertilizer cakes or not are storage temperature, storage humidity, pile or stack pressure, storage time, and curing time.

Chemical Compatibility in dry fertilizer blends is the ability of two or more materials to remain dry and free flowing when blended together. Incompatibility is evidenced by wetting, caking, and/or particle disintegration. Fortunately, only a few combinations of fertilizer materials exhibit chemical incompatibility. The only completely incompatible combination is urea and ammonium nitrate. However, combinations of urea and triple or single superphosphate can also be completely incompatible depending on the water content of the superphosphate. Additionally, urea and some sulfate-based micronutrients can exhibit wetting.
6. Common Fertilizer Materials

Following is a description of the most common fertilizer materials from around the world. Included is a brief description of the origin or production process of the fertilizer; chemical characteristics (chemical formula, nutrient content, and form); and physical characteristics (shape, size, CRH, strength, and typical moisture content).

Nitrogen Fertilizers

Ammonium Sulfate (AS) is a white, off-white, light brown or light gray crystalline material. Most AS is a byproduct of non-fertilizer industries, particularly the metal processing and plastics (caprolactam) industries. Ammonium sulfate has a chemical formula of (NH₄)₂SO₄, with a typical grade of 21-0-0-24S.

Additionally AS has a moderately high CRH, absorbing moisture when the relative humidity is about 75% or higher. Unfortunately, because AS is an essentially crystalline material and does not have much absorptive capacity, exposure above 75% relative humidity can result in a product which quickly becomes wet. Consequently, it is important to protect AS from exposure to high relative humidity.

Crystalline AS is typically irregular or “blocky” in shape. It is available in a wide range of particle sizes—for example, a “granular” screened product of about 1 to 3 millimeters down to a “powdered” screened product of about 0.3 to 1 millimeters.

In recent years, there have been a few factories built that produce a granular form of AS. This granular form of AS is essentially spherical in shape and is typically available in a particle size range of about 2 to 4 millimeters. The nitrogen guarantee for this granular form of AS is normally 20%.

Urea is a white material that is either prilled or granular (refer to the definitions of prilled and granular fertilizers). Urea has the highest nitrogen content of all solid fertilizer products and is the most widely used source of fertilizer nitrogen in the world. Urea has a chemical formula of CO(NH₂)₂ and a typical grade of 46-0-0.

The nitrogen (20%-21%) present in AS is all in the ammoniacal form and the sulfur is all in the sulfate form, both of which are water-soluble and readily available to plants. AS is acidic, which may limit its use, particularly in acid soils.

Depending on the source, the moisture content of AS can range widely, from as low as 0.1% to as much as 2%-3%. To avoid physical quality problems (caking and/or wet material), it is recommended that the moisture should never exceed 0.5%, and preferably should be 0.3% or less.
The nitrogen present in urea is all in the ureic form, which is slightly different from ammoniacal nitrogen, although it behaves similarly. Ureic nitrogen is water-soluble and readily available to plants.

The moisture content of urea (prilled or granular) is typically guaranteed to be less than 0.5%, but is actually usually less than 0.3%. Some sources of urea even have moisture contents of about 0.1%. Ideally, to avoid physical quality problems (caking and/or wet material), it is recommended that the moisture content of urea be as low as possible and not above 0.3%.

Generally, granular urea has very good handling properties (resistant to degradation and crushing) whereas prilled urea is prone to significant degradation and particle crushing if it is handled excessively, especially if prill strength is weak.

Additionally urea has a moderately high CRH, absorbing moisture when the relative humidity is about 70% or higher. Unfortunately, because urea is an essentially crystalline material and does not have much absorptive capacity, exposure above 70% relative humidity can result in a product that quickly becomes wet. Consequently, it is important to protect urea from exposure to high relative humidity.

Prilled urea, if produced properly, is very spherical in shape with a typical particle size range of about 1 to 3 millimeters. Granular urea is essentially spherical in shape (although usually less so than prilled urea) and is typically available in a particle size range of about 2 to 4 millimeters.

**Ammonium Nitrate (AN)** is a white or off-white material that is either prilled or granular. AN is second to urea as the most widely used source of fertilizer nitrogen in the world. One-half of the nitrogen present in AN is in the ammoniacal form and half in the nitrate form. Both forms are water-soluble and readily available to plants. However, nitrate in soil when oxygen is absent or present at low levels is denitrified to gaseous forms and passes to the atmosphere. Those conditions occur when a soil is saturated with water. The chemical formula of ammonium nitrate is NH₄NO₃ and it has a typical grade of 34-0-0.
The moisture content of prilled AN typically ranges between 0.15% and 0.5% whereas the moisture content of granular AN is typically less than 0.1%. To avoid physical quality problems (caking and wet material), it is recommended that the moisture content be as low as possible.

Generally, granular AN has very good handling properties (resistant to degradation and crushing) whereas prilled AN is prone to significant degradation and particle crushing if it is handled excessively.

Additionally, AN has a relatively low CRH, absorbing moisture when the relative humidity is about 55% or higher. Unfortunately, because AN is an essentially crystalline material and does not have much absorptive capacity, exposure above 55% relative humidity can result in a product which quickly becomes wet. Consequently, it is important to protect AN from exposure to high relative humidity.

AN can go through transformations of its crystal state. One of those transformations occurs at 32°C resulting in volume expansion of the prills or granules as the temperature rises above 32°C and volume contraction of the prills or granules as the temperature drops below 32°C. This can effectively cause the AN particles to crack and turn to dust after a number of cycles through this temperature. Most AN producers add stabilizers to their process that can greatly reduce the occurrence of this phenomenon. Some stabilizers are more effective than others in minimizing the breakdown of AN particles when they are exposed to temperature cycling.

Prilled AN, if produced properly, is very spherical in shape with a typical particle size range of about 1 to 3 millimeters. Granular AN is also spherical in shape (although usually less so than prilled AN) and is typically available in a particle size range of about 2 to 4 millimeters.

AN is a strong oxidizer and, under certain conditions, can explode. However, fertilizer-grade AN is generally regarded as safe as long as certain material specifications are adhered to by the manufacturer and the material is not exposed to confined spaces, elevated pressure, and contamination. Fertilizer-grade AN cannot be exploded by impact, heat, or fire alone.

**Calcium Ammonium Nitrate (CAN)** is a tan or light brown material which is either prilled or granular. CAN is actually a product made from AN with a calcium source such as limestone. CAN has a chemical formula of NH₄NO₃ + CaCO₃ and a typical grade of 27-0-0.

The nitrogen (26%-27.5%) present in CAN is half in the ammoniacal form and half in the nitrate form. Both forms are water-soluble. The nitrogen from CAN is readily available to plants with a few exceptions that involve the nitrate portion when applied to certain plants under certain conditions. The nitrogen from CAN is readily available to plants.

The moisture content of prilled CAN typically ranges between 0.15% and 0.5% whereas the moisture content of granular CAN typically is less than 0.1%. To avoid physical quality problems (caking and wet material), it is recommended that the moisture content be as low as possible.

Generally, granular and prilled CAN have very good handling properties (resistant to degradation and crushing).

Additionally, CAN has a relatively low CRH, absorbing moisture when the relative humidity is about 55% or higher. Unfortunately, because CAN is largely a crystalline material (about 75% AN) and does not have much absorptive capacity, exposure above 55% relative humidity can result in a product that quickly
becomes wet. Consequently, it is important to protect CAN from exposure to high relative humidity.

CAN may go through the same transformations of its crystal state as AN. See the description above of the AN transformations of its crystal state.

Prilled CAN, if produced properly, is essentially spherical in shape with a typical particle size range of about 1 to 3 millimeters. Granular CAN is also quite spherical in shape (although usually less so than prilled CAN) and is typically available in a particle size range of about 2 to 4 millimeters.

Phosphate Fertilizers

Single Superphosphate (SSP), also known as normal or ordinary superphosphate, is available in a powdered or run-of-pile form as well as a granular form. The process for producing SSP is similar to that for powdered or run-of-pile TSP except phosphate rock is acidulated with sulfuric acid rather than phosphoric acid. The resulting powdered or run-of-pile SSP is then either sold as is or is granulated. Most SSP is tan or light brown in color although some sources may be dark brown, brown-gray, or gray. The color has no impact on the agronomic value of SSP; all are equally effective. Like MAP and TSP, SSP is much less widely used than DAP around the world. SSP’s chemical formula is \( \text{Ca(H}_2\text{PO}_4\text{)}_2\cdot\text{H}_2\text{O} + 2\text{CaSO}_4 \) with a typical grade of 0-20-0-11S.

The amount of phosphate guaranteed (16%-22% as \( \text{P}_2\text{O}_5 \)) in SSP is that considered to be available to plants and is commonly referred to as “available phosphate.” Of the “available phosphate,” 85%-90% is soluble in water depending on the phosphate rock source. The remainder is soluble in a dilute, slightly acidic or neutral chemical solution, similar in acidity to many soils. The sulfur in SSP (11%-12% as S) is all in the sulfate form and readily available to plants.

Depending on the source, the moisture content of SSP can have an extremely wide range, from as low as 1.0% to as high as 10% or more. The lower the moisture content, the fewer physical quality problems (caking and/or wet material) observed in SSP. However, like DAP, MAP, and TSP, due to the varying amorphous nature of different SSPs, some sources can retain more moisture than others without exhibiting physical quality problems.

Generally, most granular SSPs have reasonably good handling properties, being resistant to degradation and crushing of particles during “normal” handling operations. Powdered or run-of-pile SSP can range from being very dusty when the moisture content is very low (~1%) to essentially non-dusty when the moisture content is quite high (~10%).

Typically the CRH of SSP is moderately high, absorbing moisture only when the relative humidity is about 75% or higher. However, if there is a significant amount of free sulfuric acid remaining in the SSP after production and curing, the CRH can be as low as 35%. Fortunately, because of its amorphous nature, SSP (especially powdered or run-of-pile SSP) can withstand some moisture absorption with less damage than more crystalline products like AS, urea, and AN.

Depending on the manufacturer, granular SSP is essentially spherical in shape and available in different particle size ranges between 1 and 4 millimeters; 1-3, 2-4, etc. Powdered or run-of-pile SSP can vary widely in particle size range. Most of the particles of powdered or run-of-pile SSP are between 0.1 and 1.0 millimeters although some particles can be as large as 8-10 millimeters.

Triple Superphosphate (TSP), also known as concentrated superphosphate, is typically a granular fertilizer, although it is also available in a powdered or

Figure 13. Run-of-Pile Single Superphosphate
run-of-pile form. There are two main processes used to produce TSP; an older process that produces the aforementioned powdered or run-of-pile form by acidulating phosphate rock with phosphoric acid, which is then granulated, and a newer process of producing granular TSP directly from slurry. Both sources come in a wide array of colors. The color mainly depends on the source of phosphate rock and phosphoric acid used to produce the TSP. It can range in color from light to dark brown, brown-gray, or gray. The color has no impact on the agronomic value of TSP; all are equally effective. Like MAP, TSP is much less widely used than DAP around the world. The chemical formula of TSP is $3 \text{Ca(H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$ and has a typical grade of 0-46-0.

Figure 14. Granular Triple Superphosphate

The amount of phosphate guaranteed (45%-46% as P$_2$O$_5$) in TSP is that considered to be available to plants and is commonly referred to as “available phosphate.” Of the “available phosphate,” 85%-93% is soluble in water depending on the phosphate rock source. The remainder is soluble in a dilute, slightly acidic or neutral chemical solution, similar in acidity to many soils.

Depending on the source, the guaranteed moisture content of TSP can range widely, from as low as 0.6% guaranteed by one international supplier to as high as 4% guaranteed by another international supplier. The lower the moisture content, the fewer physical quality problems (caking and/or wet material) you will observe in TSP. However, like DAP and MAP, due to the varying amorphous nature of different TSPs, some sources can retain more moisture than others without exhibiting physical quality problems.

Generally, most TSPs have good handling properties, being resistant to degradation and crushing of particles. However, the newer slurry process produces a stronger, more uniformly sized, and spherical TSP than the older process.

TSP has a fairly high CRH, absorbing moisture when the relative humidity is about 80% or higher. Fortunately, because of its amorphous nature, TSP can withstand some moisture absorption with less damage than more crystalline products like AS, urea, and AN.

Depending on the manufacturer, granular TSP is essentially spherical in shape and available in different particle size ranges between 1 and 4 millimeters (1-3, 2-4, etc). Powdered or run-of-pile TSP can vary widely in particle size range. Most of the particles of powdered or run-of-pile TSP are between 0.1 and 1.0 millimeters although some particles can be as large as 8-10 millimeters in run-of-pile TSP.

**Potassium Fertilizers**

**Potassium Chloride**, more commonly known as muriate of potash (MOP) or simply potash, is the most common source of potassium worldwide. MOP ore is mined, processed to remove most impurities, and then separated into five size fractions (soluble, special standard, standard, coarse, and granular) by screening and/or are compacted (see definitions above) and screened into a size fraction similar to the screened granular fraction. Both the screened “granular” fraction and the compacted form are referred to as granular MOP. The color of potash can vary from light pink, reddish pink, light gray, to white depending on its origin. The chemical formula is KCl and a typical grade is 0-0-60.
The potassium (60%-62% as K₂O) present in MOP is water-soluble and readily available to plants.

The moisture content of MOP is typically quite low (0.05%-0.1%) but can be as high as 0.5%. To avoid physical quality problems (caking and/or wet material), it is recommended that the moisture should never exceed 0.3%, and preferably should be 0.1% or less.

Additionally, most sources of MOP have a moderately high CRH, absorbing moisture when the relative humidity is about 70% or higher. However, there are some sources of MOP that have CRHs as low as 50%. Unfortunately, because MOP is an essentially crystal-line material and does not have much absorptive capacity, exposure above its CRH can result in a product that quickly becomes wet. Consequently, it is important to protect MOP from exposure to high relative humidity.

Granular and coarse forms of MOP are typically “blocky” in shape. The other forms (standard, special standard, and soluble) of MOP are also irregular in shape—similar in shape to sand particles. MOP is available in a wide range of particle sizes: for example, 1-3 and 2-4 millimeters for granular, 0.6-3.0 millimeters for coarse, 0.2-1.0 millimeters for standard, and 0.1-0.5 millimeters for special standard and soluble.

Generally, granular MOP has reasonably good handling properties, but because of its irregular and “blocky” shape is more prone to particle degradation during handling than more spherical fertilizers.

**Potassium Sulfate,** also known as sulfate of potash (SOP), is a distant second to MOP as a worldwide potassium source. The primary form of SOP is granular although it is also available in standard and special standard form. SOP is usually light pink or light gray in color. SOP is primarily used as a non-chloride source of potassium for certain crops such as tobacco, tomatoes, and some fruits and vegetables that have a low tolerance to chloride. It also may be a preferable source of potassium where there are sulfur deficiencies or in areas where chloride salts may accumulate. The chemical formula is K₂SO₄ with a typical grade of 0-0-50-18S.
The potassium (50%-51.5% as K₂O) present in SOP is water-soluble and readily available to plants. The sulfur (18% as S) is in the sulfate form, which is water-soluble and available to plants.

The moisture content of SOP is typically quite low (0.1%) but can be as high as 0.5%. To avoid physical quality problems (caking and/or wet material), it is recommended that the moisture should never exceed 0.3%, and preferably should be 0.1% or less.

Generally, SOP has very good handling properties because it is quite resistant to degradation and crushing of particles. Some sources, however, tend to be dusty.

Additionally SOP has a moderately high CRH, absorbing moisture when the relative humidity is about 75% or higher. Unfortunately, because SOP is an essentially crystalline material and does not have much absorptive capacity, exposure above its CRH can result in a product which quickly becomes wet. Consequently, it is important to protect SOP from exposure to high relative humidity.

Granular SOP is more or less spherical in shape. The other forms (standard and special standard) of SOP are irregular in shape, similar in shape to sand particles. SOP is available in a wide range of particle sizes: for example, 1-3 and 2-4 millimeters for granular, 0.2-1.7 millimeters for standard, and 0.1-0.5 millimeters for special standard.

**Multinutrient Fertilizers**

Fertilizers having a declarable content of at least two of the primary plant nutrients (NP, NPK, PK, or NK) are classified as multinutrient fertilizers. They can also often contain one or more of the secondary nutrients and/or micronutrients. Multinutrient fertilizers, also often referred to as compound fertilizers, are available in an almost infinite number of grades.

**Diammonium Phosphate (DAP)** is a granular fertilizer that comes in a wide array of colors. The color mainly depends on the source of phosphate rock that is used to produce the phosphoric acid which is reacted with ammonia to produce DAP. It can range in color from light to dark brown, brown-gray, gray, light green, or even off-white. The color has no impact on the agronomic value of DAP; all are equally effective. DAP is the most widely used source of fertilizer phosphorus in the world. DAP’s chemical formula is (NH₄)₂HPO₄ with a typical grade of 18-46-0.

![Figure 18. Granular Diammonium Phosphate](image)

The nitrogen (18%) present in DAP is all in the ammoniacal form. The amount of phosphate guaranteed (usually 46% as P₂O₅) in DAP is that considered to be available to plants and is commonly referred to as “available phosphate.” Of the “available phosphate,” about 90% is soluble in water. The remainder is soluble in a dilute, slightly acidic or neutral chemical solution, similar in acidity to many soils.

Depending on the source, the moisture content of DAP is typically guaranteed to be somewhere between 1% and 2% although some DAP sources may have higher amounts of moisture. Generally, the lower the moisture content, the fewer physical quality problems (caking and/or wet material) observed in DAP. However, due to the varying amorphous nature of different DAPs, some sources can retain more moisture than others without exhibiting physical quality problems.

Generally, DAP has very good handling properties, being quite resistant to degradation and crushing of particles.
DAP has a moderately high CRH, absorbing moisture when the relative humidity is about 70% or higher. Fortunately, because of its amorphous nature, DAP can withstand some moisture absorption with less damage than more crystalline products like AS, urea, and AN.

Granular DAP is more or less spherical in shape. It is available in different particle size ranges between 1 and 4 millimeters (1-3, 1.4-4, 2-4, etc).

Monoammonium Phosphate (MAP) is typically a granular fertilizer that is very similar to DAP except for the ratio of nitrogen to phosphorus. However, it is also available in a powdered or run-of-pile form. It comes in a wide array of colors, although probably less of a range than DAP. The color mainly depends on the source of phosphate rock that is used to produce the phosphoric acid which is reacted with ammonia to produce MAP. It can range in color from light to dark brown, brown-gray, or gray. The color has no impact on the agronomic value of MAP; all are equally effective. MAP is much less widely used than DAP around the world. MAP’s chemical formula is (NH₄)H₂PO₄ and typical grades include 12-52-0, 10-50-0, and 11-52-0.

The nitrogen (10%-12%) present in MAP is all in the ammoniacal form. The amount of phosphate guaranteed (48%-52% as P₂O₅) in MAP is that considered to be available to plants and is commonly referred to as “available phosphate.” Of the “available phosphate,” about 85%-90% is soluble in water. The remainder is soluble in a dilute, slightly acidic, or neutral chemical solution, similar in acidity to many soils.

Depending on the source, the moisture content of MAP is typically guaranteed to be somewhere between 1% and 2% although some MAP sources may have higher amounts of moisture. Generally, the lower the moisture content, the fewer physical quality problems (caking and/or wet material) you will observe in MAP. However, like DAP, due to the varying amorphous nature of different MAPs, some sources can retain more moisture than others without exhibiting physical quality problems.

Generally, MAP has very good handling properties, being quite resistant to degradation and crushing of particles.

MAP has a moderately high CRH, absorbing moisture when the relative humidity is about 70% or higher. Fortunately, because of its amorphous nature, MAP can withstand some moisture absorption with less damage than more crystalline products like AS, urea, and AN.

Granular MAP is more or less spherical in shape. It is available in different particle size ranges between 1 and 4 millimeters (1-3, 1.4-4, 2-4, etc.).

Potassium Nitrate is the third most widely used source of potassium. The primary forms of potassium nitrate are prilled and compacted, although it is also available in crystalline form. Potassium nitrate is usually white, light yellow, or light pink in color. Prilled potassium nitrate is primarily used as a non-chloride source of potassium for certain crops such as tobacco, tomatoes, and some fruits and vegetables that have a low tolerance to chloride. Crystalline potassium ni-
Potassium nitrate is primarily used in greenhouse fertigation systems where a high degree of water-solubility and minimal impurity levels are required. Potassium nitrate has a chemical formula of KNO₃ and a typical grade of 13-0-46.

Figure 20. Prilled Potassium Nitrate

The potassium (45%-46% as K₂O) present in potassium nitrate is water-soluble and readily available to plants. The nitrogen (13%-13.5% as N) is in the nitrate form, which is water-soluble and available to plants.

The moisture content of potassium nitrate is typically quite low (0.04%-0.2%). To avoid physical quality problems (caking and/or wet material), it is recommended that the moisture should never exceed 0.2%.

Generally, prilled potassium nitrate has reasonably good handling properties, although it is not as resistant to degradation and crushing of particles as most granular fertilizers.

Additionally, potassium nitrate has a fairly high CRH, absorbing moisture when the relative humidity is about 80% or higher. Unfortunately, because potassium nitrate is an essentially crystalline material and does not have much absorptive capacity, exposure above its CRH can result in a product that quickly becomes wet. Consequently, it is important to protect potassium nitrate from exposure to high relative humidity.

Prilled potassium nitrate is essentially spherical in shape. The crystalline form of potassium nitrate is irregular in shape, similar in shape to sand particles. Prilled potassium nitrate is basically available in one particle size range (1-3 millimeters). Crystalline potassium nitrate is available in more than one particle size range (about 0.07-0.5 millimeters from one source and about 0.1-1.0 millimeters from another source).

Other Multinutrient Fertilizers are produced by either physical blending or by one of several different chemical processes (complex fertilizers) and are mostly in granular form. The chemical formula depends on raw materials used and grade produced; numerous grades are available.

Figure 21. Chemically Produced NPK Fertilizer

Figure 22. Physically Blended NPK Fertilizer
The nutrients guaranteed in multinutrient fertilizers are mostly water-soluble. If there is any phosphate in the product, some fraction of this will be soluble in a dilute chemical solution. Both forms are readily available to plants.

The moisture content of multinutrient fertilizers can vary depending on the production process. To avoid physical quality problems, multinutrient fertilizers containing urea or AN and those produced by the nitrophosphate process should have no more than about 1.0% moisture and preferably less than 0.7%. Multinutrient fertilizers containing AS or ammonium phosphate can have moisture contents somewhat higher, but should be no more than about 1.5%.

Generally, multinutrient fertilizers have reasonably good handling properties, although some processes produce stronger, less dusty products than others.

Additionally, the CRH of multinutrient fertilizers can vary from as low as about 35% to as high as about 70% depending mainly on the raw materials used, especially the nitrogen source. Multinutrient fertilizers containing urea or AN or those produced by the nitrophosphate process can have especially low CRHs. Regardless, it is important to protect all multinutrient fertilizers from exposure to high relative humidity.

Most multinutrient fertilizers are more or less spherical, although some may be irregular or “blocky” in shape. Typically, multinutrient fertilizers are available in size ranges of 1-3, 2-4, and 3-5 millimeters.

**Other Nutrient Sources**

**Other Primary Nutrient Sources**, but less common than those described above, are ammonium chloride (~24% N), calcium nitrate (~15.5% N), sodium nitrate (~16% N), ammonium bicarbonate (~17% N), urea ammonium phosphate (~28% N and ~28% P2O5), ammonium phosphate sulfate (~16% N, ~20% P2O5, and ~8-10% S), phosphate rock (~20%-30% water-insoluble P2O5), potassium magnesium sulfate (~22% K2O, ~18% S, and ~6%-11% Mg), and several types of liquid fertilizers containing the primary nutrients.

**Secondary Nutrient Sources** are available in granular, prilled, powdered, and liquid forms. The focus here is sources of the granular, prilled, and powdered forms of calcium, magnesium, and sulfur.

The most common sources of calcium are SSP, TSP, CAN, limestone, and dolomite. As described above, SSP and TSP are available in both granular and powdered forms. CAN is available in both granular and prilled forms. Limestone and dolomite, which are generally applied as an amendment to correct soil acidity, are mainly available as finely ground powders.

The most common sources of magnesium are kieserite (MgSO4•H2O), Epsom salt (MgSO4•7H2O), potassium magnesium sulfate, and dolomite. The first three are available in both granular and powdered forms. Dolomite, generally applied as an amendment to correct soil acidity, is mainly available as a finely ground powder.

The most common sources of sulfur are AS, SSP, elemental sulfur, potassium magnesium sulfate, kieserite, and Epsom salt. All are available in various forms including granular, screened crystals, and powdered.

**Micronutrient Sources** vary considerably in their physical state, chemical reactivity, and availability to plants. The more commonly used micronutrient sources are mainly available in four physical forms (granular, powdered, crystalline, and liquid) and three chemical forms (sulfates, oxides, and chelates).

The oxides are the least soluble and therefore the least available to plants in the short term. Sulfates and chelates are water-soluble and generally more readily available to plants. However, in alkaline soils, chelates of iron and zinc are more available than sulfates. Oxides are the least expensive and chelates are the most expensive.

Most commercial sources of micronutrients are (1) produced as byproducts of other chemical or metallurgical industries or (2) manufactured from basic elements or minerals. Some of the more common micronutrient products are borate, borax, copper sulfate, copper oxide, iron sulfate, iron oxide, iron chelates, manganese sulfate, zinc sulfate, zinc oxide, and zinc chelates.
7. Labels

Labels on fertilizer bags or other containers can vary markedly from country to country and from supplier to supplier. Probably the most noticeable difference from country to country is language. However, this is unavoidable and necessary to convey the required information to the local customers/farmers.

Additionally, each supplier may have their own company logo and/or brand name for its products. This is a tool used by suppliers to identify and market their products as distinct from other supplier’s products.

However, there is certain information that should be contained on all labels regardless of the supplier or the language in which it is presented. A description of this information follows.

**Grade**, as previously defined, is a short version of the guarantees for nitrogen (N), phosphorus (P or \(P_2O_5\)), and potassium (K or \(K_2O\)) with each guarantee separated by a hyphen/dash or dot. Examples are 15-15-15 and 15•15•15. Some countries also allow for the secondary nutrients or micronutrients to be included in the grade. Examples are 15-15-15-5S and 15-15-15-1B. The grade is usually displayed in large numbers at the top of the bag. The grade is not usually considered to be acceptable as a legal guarantee.

**Guaranteed Analysis** is the supplier’s or manufacturer’s guarantee for the claimed nutrients in a specific order and format and is considered to be a legal guarantee. An example of an acceptable format for the guaranteed analysis follows.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Guaranteed Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Nitrogen (N)</strong></td>
<td>15%</td>
</tr>
<tr>
<td>_% Ammoniacal Nitrogen</td>
<td></td>
</tr>
<tr>
<td>_% Nitrate Nitrogen</td>
<td></td>
</tr>
<tr>
<td>_% (Other recognized and determinable forms of N)</td>
<td></td>
</tr>
<tr>
<td><strong>Available Phosphate (P_2O_5)</strong></td>
<td>15%</td>
</tr>
<tr>
<td><strong>Soluble Potassium (K_2O)</strong></td>
<td>15%</td>
</tr>
<tr>
<td><strong>Calcium (Ca)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Magnesium (Mg)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Sulfur (S)</strong></td>
<td></td>
</tr>
<tr>
<td>_% Combined Sulfur (S)</td>
<td></td>
</tr>
<tr>
<td>_% Free Sulfur (S)</td>
<td></td>
</tr>
<tr>
<td><strong>Boron (B)</strong></td>
<td>1%</td>
</tr>
<tr>
<td><strong>Chlorine (Cl)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Copper (Cu)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Iron (Fe)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Manganese (Mn)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Molybdenum (Mo)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Zinc (Zn)</strong></td>
<td></td>
</tr>
</tbody>
</table>

If a nutrient is claimed in the Grade or elsewhere, then it shall be listed and the amount guaranteed included in the Guaranteed Analysis. If there is no amount claimed for a nutrient, then that nutrient should not be listed in the guaranteed analysis.

For example, a guaranteed analysis for an ammonium nitrate-based 15-15-15-1B Grade using the above format might appear as follows.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Guaranteed Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Nitrogen (N)</strong></td>
<td>15%</td>
</tr>
<tr>
<td>7.5% Ammoniacal Nitrogen</td>
<td></td>
</tr>
<tr>
<td>7.5% Nitrate Nitrogen</td>
<td></td>
</tr>
<tr>
<td><strong>Available Phosphate (P_2O_5)</strong></td>
<td>15%</td>
</tr>
<tr>
<td><strong>Soluble Potassium (K_2O)</strong></td>
<td>15%</td>
</tr>
<tr>
<td><strong>Boron (B)</strong></td>
<td>1%</td>
</tr>
</tbody>
</table>

If the sources of the nutrients are shown on the label, they should be listed below the Guaranteed Analysis.

**Net Weight** as defined above refers to the actual weight of the bag or container with fertilizer minus the weight of the bag or container. This weight should be displayed prominently on each bag or container of fertilizer. In most countries, the net weight will be expressed in metric units. The net weight displayed is taken to be guaranteed.

**Name and Address** refers to the name and address of the person or company responsible for the guarantees made on the label. The complete name and address of the guarantor should be printed on the bag or container.

**Directions for Use** should be included on the label (1) when a fertilizer is produced for use on a specific crop or (2) if the use of a fertilizer might be detrimental to the development and yield of certain crops. For example, a fertilizer containing boron may have been produced exclusively for use on cotton. Conversely, fertilizers containing high levels of chloride from potassium chloride may be detrimental if used on tobacco, tomatoes, and certain vegetables.

Additionally, if a particular fertilizer is expected to be used near environmentally sensitive areas (water bodies, wetland, etc.), it may be prudent to include recommended maximum application rates per hectare.
Label Format should be presented in a readable and conspicuous form. An example of a bag with a proper label is illustrated below.

8. Bags

Functions Provided by Bags
1. In countries where (a) mechanical bulk handling equipment is unavailable and (b) small fields are the norm and, consequently, small amounts of fertilizer are used, the bag provides an easy way to handle fertilizer.
2. The bag can protect against possible adulteration of the fertilizer.
3. The bag can protect the often hygroscopic fertilizer from high atmospheric humidity.
4. In countries where fertilizer bags are often handled several times, a strong bag is essential.
5. And, of course, fertilizer bags can and are used for other purposes after being emptied.

Criteria for Selecting Bags
The most commonly used fertilizer bag around the world is the pillow-shaped 50-kilogram woven polypropylene (WPP) bag with either a loose inner bag liner or a liner laminated to the inner surface of the WPP bag. However, when deciding on bag construction, there are seven main criteria to keep in mind.

Capacity of fertilizer bags is wide ranging. However, the most common bag capacity is 50-kilogram. In some countries 25, 20, 10, and 5-kilogram bags are also used but this use is limited. In some developing countries 50-kilogram bagged products are repackaged at the dealer level into smaller capacity bags (1, 2, and 5-kilogram) for sale. There is certainly nothing wrong with this marketing technique, but the dealer should make sure that the scale used to weigh this material is accurate and the smaller bags are properly labeled.

Dimensions of bags are determined based on the bulk density of the fertilizer as well as the desired capacity (kilograms). For example, bags for urea, because it is a relatively light material, will need to have dimensions of about 60 centimeters width x 100 centimeters length to contain 50 kilograms. On the other hand, bags for DAP, which is more dense than urea, will need to have dimensions of about 55 centimeters width x 90 centimeters length.

Strength of material for fertilizer bags must be strong enough to remain intact through many handlings beginning with the bagging process, through several loading and unloading steps, ending with handling during transport to the farm. The strength of the 50-kilogram woven polypropylene (WPP) bag is determined by the (1) thickness of the WPP outer bag, which is defined by the thickness of the polypropylene tapes (strips) that are woven; (2) number of tapes per square centimeter in the WPP outer bag; and (3) the thickness of the inner bag liner. For bags that will be used for import/export, where several handlings will be required, it is suggested that the WPP material should have a weave of about 4-5 x 4-5 tapes per square centimeter. For bags that will only be used in the domestic market, where fewer handlings will be required, it may only be necessary for the WPP material to have a weave of about 3-4 by 3-4 tapes per square centimeter. The weight of the bag, which will depend on the thickness of the tape, should be about 85-95 grams per square meter. The thickness of the tape (which reflects the thickness of the bag) is measured in deniers and should be about 900-1,000 deniers. Generally, the thicker the WPP material and inner bag liner and the
more tapes per square centimeter a bag has, the stronger the bag. Obviously, thicker bags with greater concentration of tapes are more costly than thinner bags with less concentration of tapes.

**Protection from Moisture Absorption** must be maintained by the inner liner (loose or laminated) since many fertilizers are hygroscopic in nature and readily absorb moisture when exposed to relative humidity above their CRH. Inner liners for fertilizer bags are constructed of either low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE), high-density polyethylene (HDPE), or polypropylene of various densities. Regardless of which type is used, it is important to be aware that polyethylene is moisture resistant, not moisture proof. The thicker the liner is, the more resistant it is to moisture absorption from the atmosphere. Unfortunately, thicker liners are more costly. The thickness of liners is measured in microns or mils. The authors of this handbook have seen fertilizer bag liners as thin as 25 microns (1 mil) and as thick as 150 microns (6 mils). For most fertilizers, it is recommended that the liner be a minimum of 100 microns (4 mils).

**Sealing** of the WPP bag should be accomplished by sewing shut with a reasonably strong and durable nylon or polypropylene thread. Inner loose liners should either be heat sealed or tied (with string, metal ties, or rubber bands) and tucked in before the WPP bag is sown. However, the authors have seen, on many occasions, where the inner liner is either sewn along with the WPP bag or simply folded and tucked in before sewing the WPP bag. Both of these techniques are considered bad practice.

**Ultra-Violet (UV) Stability** of fertilizer bags is important although most bagged fertilizers are stored inside warehouses. The bagged fertilizers are still exposed to sunlight when being transported from one distribution point to another. Additionally, there are occasions where fertilizer bags are stored outside when the weather conditions are arid. Therefore, it is important that the bag material be UV-stabilized.

**Stackability** of fertilizer bags is important because they are regularly stacked 20-40 bags high. However, even though there are stacking patterns (described later) that are designed to lend stability to the stack, it is still important that the bag material be treated with anti-slip additives to prevent stacks from collapsing.

### Alternative Bag Types

Although the WPP bag with polyethylene inner liner is the most used bag, there are many different construction options for fertilizer bags.

**Single Layer Thick Polyethylene Bags** are used to serve as a moisture barrier and at the same time provide physical strength. This bag is usually heat sealed and either flat on both ends (box type) or pillow shaped. These two bag shapes are illustrated below.

![Single-layer polyethylene bags](image)

**An Alternative Single Layer Polyethylene Bag** is a bag with a valve, which does not require sealing. The bag is filled through this valve. The valve is then closed and tucked inside the bag itself. The pressure created by the fertilizer inside presses against the tucked valve and keeps it closed.

**A Multi-Layered Paper Bag** is common for the home garden and vegetable market in some countries. The innermost layers of paper are usually laminated with a thin polyethylene film.

**Jute** is used as the construction material for some fertilizer bags. This type bag is mainly used in India and Bangladesh.
9. Fertilizer Storage Facility Characteristics

Site Location
To determine an optimum location for a fertilizer storage facility, several factors need to be considered. From a theoretical point of view, a storage facility handling fertilizers should be located at a point which:

1. Offers proximity to the market area.
2. Has ready availability of transportation, utilities, and labor.
3. Allows the least freight cost, using the least expensive mode of transportation.
4. Has a low real estate value.
5. Has a low tax rate.
6. Is subject to low insurance costs.
7. Is not normally susceptible to natural disasters.
8. Affords the best security and law enforcement protection.

Many of these factors, however, are unrealistic or uncontrollable from a practical point of view. The principal determining factor is obviously the need to be centrally located in a major fertilizer usage area, or in a potentially significant usage area. The next important factor is that the facility be located on a main supply route. In many cases, this location is the primary town in the area, as well as the communication center, the center of administration, and the focus of agricultural activities. Because of this, people tend to locate such facilities in that area. However, consideration should be given to places central to the present or potential fertilizer consumption, even if they are not currently considered as central. Locating the storage facility in such a location may generate further business and attract other agricultural related businesses. Within the selected area, finding the right site is more difficult and will require a detailed specific onsite study. The chosen site should be served directly by the primary mode of transportation used in the area, usually trucks.

Some practical factors to choose the site within the selected location or area can then be outlined as follows:

1. Locate in the main or potentially main fertilizer usage area.
2. Locate on a major supply route.
3. Select a site served directly by the primary road and, if possible, with access to rail, and water transportation.
4. If you are not personally familiar with the local conditions of the main fertilizer usage area, make sure you consult with local people who are familiar with agriculture in the area.

Capacity Consideration
In determining the required capacity for a fertilizer storage facility, special consideration must be given to the offtake pattern, supply pattern, and safety stock.

Offtake Pattern is the amount of the different materials that are expected to be sold at different times in the year, hopefully expressed on a monthly basis or preferably on a weekly basis. This pattern is predicted by an accurate and reliable demand forecast, which is highly important in the business of supplying fertilizers. If such a demand forecast for the specific location is not yet available, it is probably best not to build a storage facility but rather to use a rented location temporarily until such a demand forecast can be formulated and tested. The monthly sales pattern should be developed for several years into the future, taking into account factors such as seasonality, types of product, availability of transportation, and the marketing situation, present and future.

Supply Pattern is the amount of different fertilizers that you will purchase at different times in the year. More than likely, the fertilizer will be available on a fairly regular basis throughout most of the year, because the production units will normally produce fertilizer on a continuous basis. However, the actual purchases to be made and placed in the storage facility will depend on many factors, particularly on the price of the material at the different periods in the year and on the expected sales to be made at the different times of the year. Also, your financial capabilities should be considered in determining the expected supply pattern. It is important to consider all these issues and develop a supply pattern plan that can be considered for determining the storage facility capacity that will be needed.

Safety Stock is the amount of each fertilizer grade that should be kept on hand in order to respond to pos-
sible extra demands and contend with possible supply interruptions. The safety stock is decided upon as a consequence of the offtake and supply patterns and laid down largely as a policy matter. However, determination of your safety stock should be based on experience, good judgment, and calculation of probable changes in supply and sales. Such factors as availability of alternative rented accommodation to cover peak requirements or use of temporary outdoor storage must be considered.

**Needed Capacity** for the storage facility can then be calculated by going through the expected purchases and sales throughout the year, calculating the maximum amount that will be in storage at any given time throughout the year, and adding to this quantity the safety stock considered necessary by the owner. This should give a good indication of the desirable storage capacity of the facility.

In cases of larger storage facilities used to supply smaller dealers or retailers, it may be decided, after carrying out the necessary financial calculations that fertilizer will be purchased on a monthly basis throughout the year to take advantage of price fluctuations. The calculation of the desired capacity of that storage facility can be carried out as shown in the following hypothetical case. It is assumed that a monthly supply of 20 metric tons is purchased and stored, and that the monthly sales, or off-take pattern, are as given on Table 2. For every month, the ending variable stock in the storage facility can be calculated by adding the monthly supply to the ending variable stock of the previous month and then subtracting the sales for that month.

**Table 2. Calculation of Warehouse Capacity**

<table>
<thead>
<tr>
<th>Month</th>
<th>Starting Variable Stock</th>
<th>Monthly Supply</th>
<th>Expected Monthly Sales</th>
<th>Ending Variable Stock</th>
<th>Ending Total Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>November</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>December</td>
<td>0</td>
<td>20</td>
<td>4</td>
<td>16</td>
<td>56</td>
</tr>
<tr>
<td>February</td>
<td>16</td>
<td>20</td>
<td>6</td>
<td>30</td>
<td>70</td>
</tr>
<tr>
<td>March</td>
<td>30</td>
<td>20</td>
<td>15</td>
<td>35</td>
<td>75</td>
</tr>
<tr>
<td>April</td>
<td>35</td>
<td>20</td>
<td>13</td>
<td>42</td>
<td>82</td>
</tr>
<tr>
<td>May</td>
<td>42</td>
<td>20</td>
<td>9</td>
<td>53</td>
<td>93</td>
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<tr>
<td>June</td>
<td>53</td>
<td>20</td>
<td>4</td>
<td>69</td>
<td>109</td>
</tr>
<tr>
<td>July</td>
<td>69</td>
<td>20</td>
<td>9</td>
<td>80</td>
<td>120</td>
</tr>
<tr>
<td>August</td>
<td>80</td>
<td>20</td>
<td>26</td>
<td>74</td>
<td>114</td>
</tr>
<tr>
<td>September</td>
<td>74</td>
<td>20</td>
<td>39</td>
<td>55</td>
<td>95</td>
</tr>
<tr>
<td>October</td>
<td>55</td>
<td>20</td>
<td>45</td>
<td>30</td>
<td>70</td>
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<tr>
<td>November</td>
<td>30</td>
<td>20</td>
<td>40</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>December</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>0</td>
<td>40</td>
</tr>
</tbody>
</table>

**Yearly Totals**  
**Average Values**  
**Minimum Stock to Maintain**
The ending variable stock thus calculated for every month is also shown in the table. From the table, we can see that in this hypothetical case, the sales during the months of September through November are in the order of about 40 metric tons. Since this is the critical time of the year, a policy can be set up to always have in store at least 40 metric tons to be able to serve customers even if the supply is cut off for 1 month. If we consider this a minimum safety stock, we can calculate the total amount to be in storage at the end of every month by adding that minimum safety stock of 40 metric tons to the variable stock previously calculated for the end of every month, which is shown in the last column of the table. By looking at this column, it can easily be seen that a maximum stock in the storage facility shows up at the end of the month of July when space in the storage facility for 120 metric tons is needed. This is therefore the needed total capacity for the storage facility in this hypothetical case. Figure 23 shows a graph of the monthly supply, monthly sales, and variable capacity in stock.

**Ventilation**

Ventilation is a critical factor in fertilizer storage, particularly under tropical and subtropical conditions because of the potential for pick-up of moisture by the fertilizer with subsequent deterioration of its physical quality. The importance of ventilation is often not appreciated in both design and operation of storage facilities.

The controlling factor in this case is the CRH of the fertilizer as defined earlier. In addition to the value of CRH as an indicator of moisture pickup, factors such as physical structure, particle size, solubility, and tendency to cake also play an important part. As we know, urea is more susceptible than diammonium phosphate or muriate of potash to be affected by moisture because of these factors.

The CRH value of urea decreases with increasing temperature, although not very rapidly. For example, the values of CRH for urea are: at 20°C = 81%, at
30°C = 73%, and at 35°C = 67%. Therefore, at a temperature of 35°C and a relative humidity above 67%, urea will absorb moisture. Unfortunately, such high values of temperature and relative humidity are commonly encountered in the tropics.

Atmospheric relative humidity changes fairly rapidly with changes in temperature, increasing as temperature decreases. As temperatures drop in the evening, the relative humidity of the atmosphere increases to very high levels overnight. In most tropical environments around the world, the overnight relative humidity will be at or above the 67% range throughout the entire year. Even during the day in tropical environments, the relative humidity will exceed 67% most of the time throughout the year.

In order to protect fertilizer in storage from the effects of moisture, the first line of defense is obviously the package, which must be of water-resistant construction—securely closed and undamaged—as indicated earlier. However, since fertilizer bags allow a small amount of moisture to permeate through the bag, a second line of protection is to avoid unnecessary introduction of “wet” air into the storage facility (i.e., any air with a relative humidity above the CRH of the fertilizer). Methods for reducing the entry of “wet” air into the storage facility include: (1) air conditioning, (2) dehumidifying, (3) heating of the air (to lower its relative humidity), and (4) limiting the entry of moist air. In most cases, the first three methods are uneconomical or impractical, and only the fourth option is a practical one.

In a humid climate, it is therefore recommended that entry of humid air to the storage facility must be avoided to the maximum extent possible. It is recommended that the facilities do not have permanent ventilation. They should, however, be capable of being ventilated. In principle, a storage facility should be ventilated only when the ambient humidity is low—60% relative humidity or less. In practice, this is likely to be when the sun is shining and conditions are dry. At all other times the facility should be kept closed, except for working access or when working conditions are unacceptable. When a product that may be affected by moisture is in storage for an appreciable time, it could be beneficial to encase the stacks in plastic or other water-resistant sheeting.

Statements have been noted to the effect that high ambient temperatures contribute to caking of fertilizers in storage. At the temperatures encountered even in closed-storage facilities in the tropics, this effect is not considered significant for the most commonly used fertilizers. It is not, therefore, necessary to ventilate storage facilities on temperature control grounds for the benefit of the product, although it may be necessary to do so to create reasonable working conditions for the people involved.

**Types of Storage Facilities**

**Regional Facilities** of large capacity with foundations and flooring of reinforced concrete (RC) with built-in waterproof layers are preferred, with an RC beam or steel frame structure, walls of brick or corrugated iron cladding, and roofs made of concrete slabs or steel frame and corrugated sheeting. This is the highest cost type of structure, but it will provide a good long-term investment and should be considered as a permanent structure. However, some facilities have been built without outside walls and are in successful operation as long as all material is properly bagged, good care is taken to protect the bags from moisture and the weather, and proper security is provided.

**Village Level** retail outlets of small capacity may have concrete or brick flooring with brick, corrugated sheet or wood sides, and corrugated sheets or tiles for roofing on steel or wooden frames. This is a good investment in the intermediate and smaller size ranges. Dirt floors are an option provided that a high dunnage of about 20 centimeters is used to prevent moisture from reaching the bags. Here again, some facilities can operate without outside walls, as long as all material is properly bagged and good care is made to protect the bags from moisture and the weather and proper security is provided.

**A Small Kiosk** may be made out of any materials available. In some cases even old cargo containers are used for this purpose. In any case, it should be noted that the fertilizer should be protected from moisture to avoid damage to the material, and care should be taken to ensure that the site facility is secure.

**Outdoor Storage** is an option that should not be overlooked for storage to cover peak demands or emergencies, or in arid or semi-arid places where there is
less chance of moisture contamination from the soil. With proper management, there is no significantly greater loss or damage and the cost of this type of storage facility is minimal. However, in order to use outside storage, the fertilizer material should be properly bagged. Bagged fertilizers are stored outdoors in several places in the world. The success of such storage procedure depends on the care in which it is done. The following points should be adhered to:

1. The ground on which the outdoor storage is to be done should be provided with good drainage facilities, not prone to flooding, flat to avoid formation of water puddles, and preferably concrete.
2. The fertilizer should be in watertight bags. Woven polypropylene bags with an internal liner are adequate, provided the bags are of the proper quality as previously described and in good condition.
3. If a moisture-resistant concrete slab is not used, then stacks should be made on dunnage. The fertilizer should be about 20 centimeters above the ground to reduce the possibility of contact with moisture.
4. Stacks can have vertical sides, but the tops of the stacks should not be horizontal; they should be sloped towards one side to avoid accumulation of water.
5. The outside bags on the sides of the stacks should have their top ends (ends through which they were filled) facing the inside of the stacks.
6. Water-resistant plastic or tarpaulins should be used to cover the tops and sides of stacks. If possible, two layers of cover should be used on the tops of the stacks to avoid seepage of water, which may find its way through seams and imperfections of one cover.
7. The covers should be tied down firmly, securing them with nets, ropes, or weights.
8. Stacking and unstacking of fertilizer should be done only at times of good weather.

The actual cost of construction of a storage facility will depend, of course, on the type of storage facility built, and on the country in which it is built. It is recommended that before the construction of a fertilizer storage facility, the local costs for the different types of construction described above be obtained and analyzed to make an informed decision of what should be installed and how it should be built.

**Corrosion**

Almost all fertilizer materials are corrosive to some degree. Water is the most important factor in enhancing corrosion effects, and it is therefore of the greatest importance to minimize this effect by keeping fertilizer and water (as liquid or as vapor in humid air) as far apart as practicable by:

1. Properly designing of facility.
2. Using the correct materials in the construction of the facility.
3. Operating the facility properly and using the proper bags to protect the fertilizer.

Measures should be taken to protect both the storage facility and the fertilizer. As previously stated, the first defense against having the fertilizer come in contact with moisture is to use the appropriate bags and to treat the bagged material properly so as not to damage the bags. It is also important that roofs and drainage systems be kept in good condition to avoid water getting on the ground where the fertilizer is stored. Any water or fertilizer spillage on the ground should be cleaned up immediately. Also, as mentioned earlier, the ambient humidity of the facility should be controlled as low as possible, if the facility is built in a way that this is possible.

However, there will be situations in which fertilizer and moisture will come together; because of this, the bottom parts of the facility should be protected against corrosion and/or erosion. Using care and common sense in the selection of materials of construction will avoid many problems. For example, concrete floors plus the bottom 20 centimeters of the walls should be made resistant to moisture migration and the acidifying effects of fertilizer. Steel should be well protected with suitable corrosion-resistant paint. Fittings for corrugated roofs should preferably be of stainless steel, although ordinary steel roof trusses have given long and satisfactory service in fertilizer storage facilities even in port locations. Steel frame structures with corrugated sheet cladding can give satisfactory service, although the bottom of the walls tends to corrode. This can be overcome by making the lower sections brick or concrete. Wood is a good construction material for small fertilizer storage facilities because it is naturally resistant to corrosion and erosion. If treated, it can have a long life.
10. Inventory Control and Operation

In order to optimize the operation of the storage facility, improve control of the inventory, and reduce operating costs, it is necessary to develop a series of operating procedures, which are specific for each location. However, the following points should be implemented for efficient operation of a storage facility:

1. Prepare a layout plan.
2. Stack bagged products properly.
3. Keep a stock card for each stack as well as a stock record in the office.
4. Practice good housekeeping, i.e., remove all damaged bags, place product in good bags, immediate cleanup of all spillage, and maintain a clean and tidy facility at all times.
5. Maintain the building in good condition.
6. Closely supervise labor, safety, and security arrangements.
7. Limit access only to those with business in the facility.
8. Record all movements of products (receipt and dispatch).

Optimum Layout

It is very important that the layout used in the fertilizer storage facility be properly designed to make the best use of the available area. It is important to leave free space to allow moving within the facility to get to the proper stack, permit the stacking and unstacking of materials, and be able to move materials in and out of the facility. In general, it is important to leave walking space between the stacks and the walls and to make the central aisle large enough to move fertilizer in and out of the facility. Also, avoid leaning the product against the walls, which may not be able to withstand the weight.

To determine how much fertilizer can be stored per square meter of storage area, calculate from the densities of the materials involved, referred to as tapped bulk densities. Such density values can be used directly when determining the amount of material to be stored in bulk. If the material is to be stored in bags, the storage density will be about 5%-10% (use 7.5%) less than the density of the product in bulk because of the empty spaces between bags. Therefore, storage densities that should be used for some common products, when stored in bulk and in bags, are shown in Table 3.

Table 3. Tapped and Adjusted Bulk Densities for Common Fertilizers

<table>
<thead>
<tr>
<th>Product</th>
<th>Tapped Bulk Density Use for Product Stored in Bulk (metric tons per cubic meter)</th>
<th>Adjusted Tapped Bulk Density Use for Product Stored in Stacked Bags (7.5% Less than Tapped Bulk Density) (metric tons per cubic meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prilled urea</td>
<td>0.86</td>
<td>0.80</td>
</tr>
<tr>
<td>Granular urea</td>
<td>0.86</td>
<td>0.80</td>
</tr>
<tr>
<td>Granular ammonium sulfate</td>
<td>0.98</td>
<td>0.90</td>
</tr>
<tr>
<td>Prilled ammonium nitrate</td>
<td>0.96</td>
<td>0.89</td>
</tr>
<tr>
<td>Granulated DAP</td>
<td>1.10</td>
<td>1.02</td>
</tr>
<tr>
<td>Granulated MAP</td>
<td>1.10</td>
<td>1.02</td>
</tr>
<tr>
<td>Granulated TSP</td>
<td>1.20</td>
<td>1.11</td>
</tr>
<tr>
<td>Granulated MOP</td>
<td>1.10</td>
<td>1.02</td>
</tr>
<tr>
<td>Average material</td>
<td>1.02</td>
<td>0.94</td>
</tr>
</tbody>
</table>
For example, on a square meter of storage space, if you make a stack 4 meters high, you can store about 3.2 metric tons of prilled urea (0.8 x 4.0 = 3.2). This calculation relates fairly well to actual experience, assuming that the bags used are about 100 centimeters long by 60 centimeters wide before filling, that they reduce in size to about 75 centimeters long by 50 centimeters wide after being filled, and that you will be stacking these bags according to one of the two patterns illustrated in Figure 25. However, in establishing your particular storage standards, it would be useful to make actual measurements of how much product you can store in a given unit area, using your particular products and particular storage methods.

In designing the layout, you must plan for an allowance of at least one-third of floor space for access to the material in larger facilities, and up to 50% in smaller facilities. This appears to be a high portion of the warehouse space to be devoted to access; but it is fairly realistic in practice, and it is a figure that is frequently underestimated. If, for example, a warehouse is purchased, rented, or built with a storage area of 8 meters by 8 meters, we can calculate the amount of material that it can hold by using the following procedure:

1. Determine the number of stacks you will need. If you will be handling up to four different materials, you should plan to have at least four stacks. Let us assume they will be granular urea, granular DAP, granular MOP, and granular TSP.
2. When defining where the stacks will be, leave at least 30 centimeters between the stacks and the walls, and about 1.4 meters between the stacks to allow storage and removal. The area that can be used for the four stacks in a warehouse 8 meters by 8 meters is illustrated in Figure 24. Each of these stacks would have an area of 3 meters by 3 meters, or 9 square meters, so the total stacking area will be 4 stacks x 9 square meters per stack, or 36 square meters, which is only 56% of a building measuring 8 meters by 8 meters (64 square meters). The un-

![Figure 24. Stacking Area for an 8-Meter x 8-Meter Warehouse Facility](image-url)
used area is needed for access to the material, and this access area will be of a lower percentage in larger warehouses.

3. Determine how high the stacks can be, leaving enough room for dunnage at the bottom of the stack and enough space at the top for handling the top bags. Further details about stack height are given in the next section. For the example being considered, let us assume that the available warehouse can support stacks 4 meters high, and still have room at the bottom and top of the stacks for dunnage and handling. This means that each stack will be able to store up to 9 square meters x 4 meters, or 36 cubic meters.

4. Determine how much material can be stored in each stack, considering the bulk density of the material to be stored. Assuming that the four stacks will be used to store the four materials of our example, the capacity of each of these stacks can be calculated by using the adjusted bulk densities given in Table 3. This considers the empty volume between bags and that the fertilizer will be in a packed state of bulk density. In this case, a 36-cubic-meter stack of prilled urea will hold 36 cubic meters x 0.80 metric tons per cubic meter, or 28.8 metric tons of product. In the case of granular DAP, a similar stack will hold 36 cubic meters x 1.02 metric tons per cubic meter or 36.7 metric tons; in the case of granular MOP, such a stack will hold 36 cubic meters x 1.02 metric tons per cubic meter or 36.7 metric tons; and in the case of granular TSP, a similar stack will hold 36 cubic meters x 1.11 metric tons per cubic meter or 40.0 metric tons.

5. Make a summary of the total capacity of the warehouse by adding together the capacity of the different stacks. In the case of the example, this would be 28.8 + 36.7 + 36.7 + 40.0 = 142.2 metric tons. It is important to realize that the numbers calculated will vary according to the different sizes of the bags to be stored, but the capacity of the warehouse will be near the value calculated.

6. It should be remembered that these calculations only determine the capacity of the stacking area. A proper warehouse should also have a separate area for an office, for rebagging spilled product, for storing equipment and empty bags, and for doing other administrative activities.

Stack Height

Considerable misunderstanding exists regarding the height to which bagged fertilizer can be stacked manually or in palletized form. Statements such as “you cannot stack more than 20 bags high” assume that above this number the bags may split, the granules may be crushed, or the product will cake. However, these effects are not generally experienced in practice except for some caking of the lower layers of some materials in long-term storage.

A stack of 20 bags of urea is around 3 meters high. Stacks of 35 bags are not uncommon. In some places the height of stacks is limited, mostly on stability grounds, to 35 bags for woven polypropylene bags and to 45 for single-film polyethylene. At these heights, properly constructed bags and reasonable-quality granules should not suffer any damage. Fertilizers stacked in bulk piles may be up to 15 meters or more than twice as high as a 45-bag stack. For palletized material, manually formed pallets of six layers x five bags (1.5 metric tons) may be stacked three or four high.

In practice, the maximum stacking height should be determined by the safety and stability of the stack, as determined by the judgment of the owner/manager, considering the skill and experience of the workers and the available height of the building.

Stacking Patterns

In order to protect the stored fertilizer, it is necessary to stack the fertilizer material in a proper way. This will include:

- Using dunnage at the base to prevent ground moisture from penetrating the bottom bags (see the section on dunnage below). Alternatively, if the floor is constructed of concrete and is coated with a moisture-resistant agent, dunnage may not be required.
- Storing only one product per stack to avoid confusion when moving it or selling it.
- Placing a label on each stack indicating the material contained, its origin (company that produced it), and the date on which it arrived at the storage facility.
- Leaving separations between stacks and walls as well as between stacks.
• Properly arranging the bags on the stack according to the aspect ratio of the bags to avoid instability of the stacks.

The first four items on the list are self-explanatory, and no further comments are required for them to be properly implemented in the storage facility. Following are comments related to the arrangement of the bags on the stack according to their “aspect ratio.”

Aspect ratio is the ratio of the width to the length of each bag. This is an important factor because it affects the stacking options in storage. If bags are placed in the same direction one on top of each other, the stacks made this way have the tendency to fall after just a few layers because there is no interlocking between the different layers. It has been determined that if each layer of bags is made to interlock with the previous layer, these stacks will be very stable, and could be made relatively high. To be able to interlock the bags, their aspect ratio is important. Although in some unusual cases, bags with an aspect ratio of 1 to 1, or 2 to 1 may be obtained, in most cases, the size of bags that are used in commercial applications have an aspect ratio of 2 to 3 (referred to as 2:3). This means that the width of the bag is very close to about 2/3 the size of its length, so the explanation of interlocking bags will be limited to these types of bags.

Bags with an aspect ratio of 2:3 are the most common type of bags used, yielding good stacking and interlocking characteristics. Bags of this aspect ratio are normally stacked in layers of either 5 or 6 bags per layer as follows:

• If 5 bags per layer are used, the arrangement of the 5 bags on 2 subsequent layers is shown on the top part of Figure 25. When this is done, each layer will interlock with the bags of the layer under them to provide stability to the stack. When constructing pallets to be used for this bag arrangement, they need to be constructed of a size that will accommodate the bags. If, for example, the full bags measure 50 centimeters wide by 75 centimeters long, the pallets

![Figure 25. Common Interlocking Stacking Patterns for Bags With a 2:3 Aspect Ratio](image-url)
for this bag arrangement should have a size of 1.50 meters by 1.25 meters.

- When an arrangement of 6 bags per layer is used, the positioning of these 6 bags on 2 subsequent layers is shown on the bottom part of Figure 25. Assuming again that the full bags measure 50 centimeters wide by 75 centimeters long, the pallets to be used for such bag arrangement should have a size of 1.50 meters by 1.50 meters.

- A general arrangement for bags, referred to sometimes as “pinwheel” arrangement that will work with bags of any aspect ratio, except with bags that have the same width as length (aspect ratio of 1:1), is shown in Figure 26. In this case there will be only 4 bags per layer on each pallet, and there will be an unused space in the center of each bag layer. If we use this arrangement with the full bags that measure 50 centimeters wide by 75 centimeters long, the pallets would have a size of 1.25 meters by 1.25 meters, and there will be an unused space in the center of each bag layer of 25 centimeters by 25 centimeters.

Following up on the example warehouse shown on Figure 24, if full bags have a size of 50 centimeters by 75 centimeters, and we wish to make stacks that measure 3 meters by 3 meters as suggested before, we could use the bag arrangement shown on the bottom of Figure 25. In this case, we would be able to place four pallets each measuring 1.50 meters by 1.50 meters on the floor for each stack. Each layer of bags on the stack would then have a total of 24 bags, with a total weight of 1,200 kilograms, or 1.2 metric tons per layer.

**Shrinkage**

Shrinkage is a term used to refer to losses of product during the handling and other operations at a storage facility. In analyzing the problem, we should realize that there are three types of “losses” that affect fertilizer materials.

1. Measurement errors result in no actual loss of material.
2. Theft results in loss to the system.
3. Actual physical losses are a result of either quantity loss (mainly due to spillage during handling) or quality loss (due to caking and lumps caused by contamination with moisture or by bag breakage due to rough handling).

To reduce the amount of losses in a storage facility, care should be taken to avoid or reduce these problems.

**Measurement Errors** can be eliminated or seriously reduced by improving the records kept and by improving the maintenance and calibration of any scale used at the facility. It is important to weigh the material being purchased and to ensure that the facility is receiving the amount being reported by the entity selling you the fertilizer. If material is purchased in bags, it is important to weigh as many bags as practical to ensure that the weight of the bags is correct. In some cases, bags may have 1-2 kilograms more or 1-2 kilograms less than the amount indicated on the bag. In other cases, bags may be substantially short weight, by as much as 5-10 kilograms, due to pilferage.

In rebagging the product at the facility, care must be taken to avoid losses by ensuring that the bags be-
ing filled have the correct weight and by keeping the fertilizer protected at all times to avoid damage. As indicated above, it is important that the scales used are properly maintained and calibrated.

Theft is quite common in many places and is either ignored or just accepted and given the name of “transit loss,” or just plain “shrinkage.” Keeping good records and maintaining security controls with locks and guards should minimize or totally eliminate theft from storage. Theft during transit to the storage facility is a more difficult problem, but can be minimized by counting bags during unloading and, if shortages are detected, holding the transit company responsible.

Actual Physical Losses can be due to spillage during handling, caking and lumps caused by contamination with moisture, or bag breakage due to rough handling. To eliminate these losses, it is necessary to avoid handling the material in a rough way and to protect it from moisture as indicated in other parts of this manual. Always remember that fertilizer granules are relatively fragile and that fertilizer is damaged by moisture. Some rules to follow to avoid physical damage to fertilizer are:

1. Do not use hooks to move bags.
2. Do not perform operations during wet weather.
3. Do not drop bags of fertilizer from excessive heights.
4. Do not use ropes to handle bags.
5. Avoid unnecessary handling of bags.
6. Do not allow rough handling of the bags.

Shrinkage can also be a result of using faulty bags or improperly sewing the bags whether the bagging is to be done at the production site or the storage facility. It is important to use good quality bagging materials and to close the bag properly.

In many places, shrinkage is reported to be in the order of about 1% each time the material is handled; this is a high loss, which should not be accepted as a natural occurrence. By using the procedures indicated above, this level of loss can be minimized or even eliminated.

Dunnage

Dunnage is a term used to represent something that is placed under the stacks to protect the fertilizer from moisture damage. The ideal dunnage consists of wooden pallets, which raise the fertilizer bags and permit air to circulate under the stack, removing the moist air. If pallets are not available, an alternative is to fill bags with a dry substance such as dry sand and use these bags for the first layer of the stack. It is extremely important for these bags, referred to as dunnage bags, to be well marked and even made of a different color, so that they are not sold as fertilizer.

When neither pallets nor dunnage bags (as described above) are available, a plastic sheet is placed on the floor before stacking the fertilizer to protect the bottom bags from the moisture that seeps through the floor from underneath. This is particularly important for concrete floors not treated with a moisture-resisting agent to avoid moisture migration through it.

Record Keeping

It is essential that good records be kept. Keeping good records will help you determine when you need to reorder materials and how much to buy of each needed product. It is also important so that you can respond immediately to a potential client who is interested in a stated quantity of a specific material.

The following listed information needs to be recorded on a daily basis in order to keep useful records.

1. List quantities of each product in storage at the beginning of the day.
2. List quantities of each product received that day.
3. List quantities of each product sent out that day.
4. List quantities of each product lost or damaged that day, giving details of how and why this happened. This will be useful in avoiding these losses in the future.
5. Record closing stock (quantities of each product remaining on hand).
6. Record quantities of each product in transit (shipped out but have still not reached the purchaser).
7. Record quantities of each product ordered, but still not received at the storage facility.
This information should be recorded on a daily basis on forms specifically designed for this purpose and stored in an assigned and secure location. If the storage facility is owned by an entity or person not located in the same city, this information should be transmitted daily to them, along with weekly, monthly, quarterly, and/or annual summaries, as may be agreed.

It is also necessary to perform an inventory check on a regular basis to ensure that the records match with the real stock. This should be done at least on a monthly basis with a more detailed inventory taken quarterly. A formal annual inventory should be undertaken for audit purposes.

If the owner of the storage facility does not directly operate the facility, he should coordinate independent unannounced spot checks on stocks and operations to ensure that matters are being handled properly.

**First-In, First-Out Considerations**

It is always good to sell and move the fertilizer as soon as possible. If it stays in storage for a long time, the material has a greater chance of being damaged by caking, too much handling, spills, or absorbing moisture. Because of this, it is usually said that storage facilities should operate on a first-in, first-out basis, meaning that whenever a given type of material is sold and has to be shipped out of the facility, the oldest material of that type in storage should be the one to be delivered. However, although this is a good general policy, it should not be applied always in a strict form, because it may lead to double handling and extra cost in some cases. A limit should be placed on the maximum time particular products should be allowed to be kept in storage, and when that time limit comes up for a specific stack, that stack should be marked to be the next one to be shipped out when a call for that type of product is received. On a highly seasonal off take, where stocks may build up over several months, first-in, first-out may be applied more strictly.

**Management**

Good management in the storage facility is vital, yet its importance is often not appreciated. The storage facility is the last point where the fertilizer is handled before it is received by the customer, so the documents initiated here are critical to all financial activities.

A good manager will ensure firm control over all activities associated with care of the facility as well as the stock under his control, which may represent large amounts of money for the owner of the operation. If the manager of the storage facility is not its owner, he must accept responsibilities in these areas and have sufficient freedom of control and authority to operate efficiently within established limits set by the owner.

If the facility is owned by an entity or person not involved in its daily operation, this owner entity or person must lay down storing policies and procedures and ensure that they are complied with by the operating personnel. Those owners must also maintain close contacts with the people running the operation, be responsive to problems that develop, and be prepared to assist with information, services, and training as necessary.

**Handling of Fertilizers**

If fertilizers are not handled properly, losses will occur. This is particularly true of fertilizer materials that will be damaged if exposed to moisture or if the granules are subjected to pressures that will crush them. Therefore, handling has to be carried out in specific ways. There are guidelines for handling fertilizer when it is in bulk (without bags) just as when it is in bags. We will mention bulk handling somewhat, but will deal mainly with handling bagged materials because most fertilizer to be handled in the storage facilities will be bagged.

**Bulk Fertilizers** almost always show somewhat more caking after being stored in a large pile than in smaller piles; most finished fertilizers cake to some extent. Generally, the caking is more noticeable at the bottom of the hold because of the greater pressure from the material above. With good quality fertilizers, this caking can be light to moderate and will probably disappear as the material is handled for further processing, blending, or bagging.

The most important rule that should be stressed with bulk fertilizer is that the facility where this material is stored should provide the necessary protection against ambient moisture. It is important that the relative humidity of the ambient air in contact with the fertilizer is lower than the critical relative humidity for that material, as explained earlier.
Bagged Fertilizers, as well as bulk fertilizers, have a tendency to cake. Even good quality fertilizers are likely to be somewhat caked on arrival from overseas shipments. With good material, the caking is relatively light and breaks down fairly easily by normal handling, so the bags recover their flexibility.

With certain products, particularly urea, if the product is (1) unconditioned (no anticaking treatment) or (2) of poor physical quality (containing small particles and fines), then the product may cake quite hard, and you may then be dealing with 50-kilogram blocks, which are much more difficult to handle and stack.

Fertilizer bags are fairly difficult to handle because the bags are relatively slippery and hard on the hands, which encourages the use of hooks. This is of such significance in fertilizer handling that we devote the following paragraphs to this device.

Handling with Hooks is the greatest single source of damage and loss in handling bagged fertilizers, particularly at the ports.

The problem is not simply that the holes caused in the bags may lead to leakage of product. The real problem is the puncturing of the inner, water-resistant liner. As noted earlier, fertilizer must be protected from moisture; so the bags should have an inner water-resistant liner. Once this liner is punctured, moisture can readily enter the bag causing severe caking and physical loss of quality in addition to the physical loss of fertilizer. This damaging effect continues throughout the system of handling and storage right up to the time that the fertilizer is used by the farmer. It is then very important that bagged fertilizer should not be handled with hooks.

In considering how to stop the use of hooks, we must start by recognizing:

1. Hooks make the handling of bags an easier task for the handler.
2. Picking up 50-kilogram bags manually is difficult.
3. Handling 50-kilogram bags is very hard physical labor.

If we had to do this job ourselves, we would find it much easier to pick up bags using hooks than without them. In order to eliminate use of hooks, it is therefore necessary to compensate for the increased difficulty. It is very easy for hooking to creep back in if management relaxes its efforts.

Key Points in Handling Bagged Fertilizers are related to the fact that fertilizers are damaged by moisture and that fertilizer granules are relatively fragile. The important points to be considered in handling fertilizers are therefore:

1. No wet weather operations.
2. No hooks.
3. No unnecessary handling.
5. No rough handling.

Good Housekeeping

Bad housekeeping in a fertilizer storage facility can be the cause of losses of product and other materials, and it can also be the cause of injuries to visitors or to the people who work at the site. To avoid these possible problems and losses, it is important to maintain order and cleanliness in the storage facility all the time. It is very important to remove and rebag all damaged bags, and to immediately clean up all spillages. The following is a checklist of activities that should be performed to maintain a clean and tidy storage facility:

Good Housekeeping Checklist

- Pick up spills as soon as they occur and rebag the spilled material as soon as possible before its quality is damaged.
- Pick up all materials dropped on the floor, such as pieces of empty bags, etc., to avoid clutter.
- Put away all tools after maintenance activities.
- Properly clean and put away weighing and bagging equipment after use.
- File away all documents, particularly important ones, such as shipment records, inventory control, etc.
- Avoid spillage of water or other liquids and pick these spills up as they occur.
- Avoid polluting water bodies (rivers, creeks, sea, etc.).
- At the end of every day:
  - Clean up the facility.
  - Inspect stacks to make sure they are properly stacked.
  - Inspect that all outside stacks are properly protected.
  - Make sure every stack is properly labeled.
  - Secure all doors.
Cost for Operation of the Storage Facility

The costs of operating a fertilizer storage facility will depend on the country and the particular location of the facility. To estimate such costs, it is important that the following items be considered in the calculations:

1. Cost of building ownership or rental.
2. Inventory costs.
3. Operating costs.
4. Handling costs.
5. Product loss and damage costs.

The Cost of Building (Ownership or Rental) a storage facility with dimensions of 8 meters long by 8 meters wide (120-160 metric ton capacity) and built at a cost of US $108/square meter would be about US $6,912. If this building is to have 20 years of useful life and the funds to build it are obtained on loan from a lending institution at an annual rate of 15%, the yearly amount that has to be repaid to the lending institution can be calculated using the equation for Capital Recovery Factor (CRF), which is:

\[
\text{Capital Recovery Factor (CRF)} = \frac{i(1 + i)^n}{(1 + i)^n - 1}
\]

where: 
- \( n \) = the number of years of the loan
- \( i \) = the yearly interest at which the money was borrowed

Substituting the assumed values of \( n = 20 \), and \( i = 0.15 \) in the equation, the CRF is 16%, which means that the yearly repayment during 20 years to the lending institution for constructing this storage facility will be about US $6,912 x 0.16 = US $1,106 or about US $92.16 per month. If this is a rental building, its owner will probably be paying a similar amount to a lending institution, and the payment to this owner will probably be this amount plus his profit. Considering that the owner’s profit is probably about 20%, the rental payment may be about US $92.16 x 1.20 = US $110.60 per month or about US $1,327 per year. However, if it is an older building that has already been paid for or depreciated by its owner, the monthly rental cost may be considerably less.

The fertilizer sales must bring back enough funds to the storage facility to pay for these costs. Assuming an annual sales volume of 240 metric tons as discussed in Section 9, each metric ton of fertilizer sold should bring in enough funds to pay for its share of the cost of the building. In the case of the constructed building mentioned above, this amount would be US $1,106/240 metric tons or US $4.61/metric ton, and in the case of the rented building mentioned above, the amount would be US $5.53/metric ton.

The Cost of Inventory is probably the highest of all costs. The cost of the material in inventory should include the price paid for the material when bought, plus the cost of transporting it to the storage facility, plus the interest being paid to the lending institution that lent the money to purchase it. Assume that the average fertilizer price from your supplier is US $200/metric ton and that transportation from the supplier to your facility adds US $20/metric ton, you would be paying about US $220 for every metric ton in your warehouse. Assuming that the average amount of fertilizer in storage is 78 metric tons, as shown in Table 2, then the cost of this material is US $220 x 78 = US $17,160, and the interest that needs to be paid to the lending institution on a yearly basis at the 15% rate assumed above is US $2,574. Each of the 240 metric tons sold every year would need to bring back US $2,574/240 = US $10.73 to pay for the material in inventory.

The Operating Cost includes the cost of all expenses associated with the operation of the facility. This will include the cost of any permanent operators or employees operating the facility, as well as the cost of electricity, pallets, covers for the stacks, repairs to the building and equipment, cost of bagging equipment (if used), bags to have in stock to replace damaged ones, tools, safety equipment, property taxes, and any other continuous expenses that may be required for the operation of the facility. This amount will vary considerably between facilities, depending on their location, size, and many other specific factors. If we consider a small facility with no permanent employees except the immediate family members of the owners, the assumed operating costs may be in the order of about US $2.00-$5.00/metric ton sold.

The Handling Cost for unloading fertilizer from a truck and stacking it in the storage facility as it is received, as well as unstacking it and loading on a vehicle for the customer when it is sold, requires several
people but only for short periods of time. Instead of having such people at the facility all the time and having to pay them salaries even during days when there are no arrivals or deliveries, it is customary in most storage facilities to hire these people for services only when needed. The cost of this operation will obviously depend on the location of the facility and will have to be calculated for those specific conditions. For our assumed calculations, we will assume a cost of US $1.00 for each operation, so each ton will cost US $2.00 for handling (US $1.00 for unloading and stacking, and US $1.00 for unstacking and loading). It is assumed in our calculations that the cost of transportation of the fertilizer to the customer will be paid by him. If not, this cost would have to be added to the selling price.

**Product Loss and Damage Costs** are reported to be about 1% every time the material is handled and, as indicated, this is a high loss, which should not be accepted as a natural occurrence. For our calculating purposes, we will assume that after recovering the material spilled during handling, the losses can be kept to about 0.5% of the material sold.

**Total Costs** calculation for providing a metric ton of product to a purchaser at the storage facility is illustrated by the following.

<table>
<thead>
<tr>
<th>Material cost:</th>
<th>US $/metric ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Price from supplier</td>
<td>200.00</td>
</tr>
<tr>
<td>• Transportation from supplier to facility</td>
<td>20.00</td>
</tr>
<tr>
<td></td>
<td><strong>220.00</strong></td>
</tr>
</tbody>
</table>

Cost of operation of the storage facility:
- • Cost of building (we will assume a rented facility) 5.53
- • Inventory costs 10.73
- • Operating costs 3.50
- • Handling costs 2.00
- • Product loss and damage (0.5% of all costs of operation) **1.21**
| | **22.97** |

Total cost before local, income, and other taxes and profit **242.97**

The **Selling Price** for the fertilizer should be calculated to recover all above costs plus all taxes and make a profit.

It should be noted that the cost of inventory is the highest. That amount can be lowered by reducing the quantity of material stored as a safety amount. It is also important to note that if not strictly controlled, the loss and damage costs could severely affect the profits expected from the operation of the storage facility. Another concept to keep in mind is that costs can be lowered or spread by using the facility as a multi-product location for storage of other materials such as crops, pesticides, seeds, or other farming products or equipment. To increase sales and therefore reduce costs, consideration should also be given to pricing incentives or early delivery rebates to reduce peak stock requirements and inventory levels, as well as options for short-term or outside storage to cover peak periods.

### 11. Safety and Security Considerations

Safety is a very important aspect of any worksite, and making the workplace safer is one of the most productive investments management can make. Apart from the personal pain and problems they cause, accidents account for monetary business losses. To be safe and avoid accidents, take necessary precautions to avoid being hurt and to avoid causing pain, injury, or loss to others.

**Preventing Accidents**

To avoid safety problems in relation to fertilizer storage and handling, it is important to follow safe procedures at all times in the storage facility. Particular consideration should be given to the following actions:

**Stack Fertilizer Bags Properly** to minimize the possibility of bags tumbling from the stack and injuring people. The proper way to stack fertilizer bags was previously described in this handbook.

**Pick up Fertilizer Spills** from the floor to prevent people from slipping and falling. Fertilizers become moist and slippery when outside of bags, and this situation becomes worse when several materials are mixed together.

**Avoid Contamination of Fertilizers** with foreign materials, which may lead to explosion hazards. Particular care should be given to fertilizer materials that contain nitrates.
Avoid Mixture of Fertilizer Materials that may lead to explosion or fire hazards, particularly when nitrate-containing materials are involved. Mixtures of fertilizers usually become very hygroscopic and absorb moisture from the atmosphere, which presents storage and handling problems. A mixture of urea and ammonium nitrate will become very wet; if both of these materials are being handled, they should be stored far apart from each other.

Prevent the Contamination of Food with fertilizers, which would be hazardous for people to eat. This contamination should be avoided at all costs, and whenever possible, fertilizer and food should be stored in different rooms.

Avoid Potential Fertilizer Fires, particularly those containing nitrates and chlorides. Those may lead to what is referred to as “cigar burning” in which the oxygen required for burning is generated during the burning process itself making these fires very difficult to extinguish. In this case, large amounts of water are needed to extinguish the fire, and traditional extinguishers will not work on such fires.

Avoid Personal Accidents by always requiring at least two people to be present when performing tasks around machinery so one can help the other in case of an emergency. Be careful when in the fertilizer storage area; do not play games within the storage area. Lift bags and other heavy objects by squatting and then straightening your legs rather than by bending your back.

Provide Awareness of the Hazardous Nature of the materials handled. In many parts of the world, Material Safety Data Sheets (MSDS) accompany all materials sold industrially. These MSDS, which are described later in this handbook, describe the hazardous nature of the materials and give indications of the proper way to handle them to avoid health problems and other possible hazards.

Minimize Scaffolding Accidents by having the necessary equipment and instructions on hand.

Respiratory Protection Masks should be provided and used if there is a danger of fumes.

Avoid Inadvertent Operation of Machinery that is being repaired to prevent injury to personnel. This can be accomplished by putting a lock on the circuit breaker and a tag indicating that the machinery should not be energized or started.

Regularly Inspect Electrical Wiring and immediately repair or replace faulty wiring.

Use Machine Guards over moving parts to prevent harm to people from clothing being tangled with the moving parts of the machines.

Provide Proper Training to all workers operating equipment.

Additional Safety Guidelines, as applicable, should be considered.

- Electric safety guidelines.
- Welding procedures.
- Proper control of pressured air and steam.
- Procedure for entry into confined spaces (tanks or other equipment).
- Laboratory safety guidelines.
- Use of hardhats, gloves, safety glasses or goggles, dust masks or respirators, and ear plugs as needed.
- Rules applicable to motorized equipment when using forklifts or other vehicles.

Institute a Safety Program

A safety program should be formulated and implemented, and a person should be identified as the safety officer. This person shall ensure that all the safety conditions are properly followed and should maintain written records of all safety-related activities within the workplace. It is important that all workers are trained in safety matters so that they can avoid safety problems in the workplace. The person responsible for safety should also have the following responsibilities:

- Implement the safety training of new employees.
- Oversee the use of personal protective equipment.
- Develop a first-aid program and look after first-aid kits.
• Look after guards for moving equipment, if applicable.
• Oversee fire protection and building safety.
• Oversee equipment safety: electrical, tools, vehicles, etc.
• Maintain a list of hazardous materials.
• Label hazardous materials as a way to communicate dangers to employees.
• Keep up with the MSDS information sheets.
• Develop any other way to maintain a safe workplace.
• Investigate accidents and devise procedures to avoid future occurrences.

Material Safety Data Sheets Information
In many places around the world, MSDS are provided to the buyer when purchases of chemicals are made. This applies to fertilizers, and in many cases you will receive these sheets along with the material purchased. It is important that when purchases of fertilizer materials are made, particularly from overseas locations, the MSDS received are studied and then filed in a place where they can be retrieved when needed to solve emergency situations.

The main information contained in an MSDS document includes:

• Specific identification of the material, also indicating any other common chemical names.
• Physical and/or chemical characteristics of the material.
• Acute and/or chronic health effects and related health information.
• Exposure limits.
• Whether the chemical is a carcinogen.
• Precautionary measures to take in handling the material.
• Emergency and first-aid procedures related to this material.

Security Considerations
It is very important to provide as much security as possible for the storage of fertilizers, not only to protect the investment made by the owner of the storage facility, but also to protect outsiders from safety hazards. Some fertilizers have an intrinsic danger associated with them, particularly those containing nitrates, and could therefore be dangerous to children or people who are inexperienced about these dangers. Also, since some of these nitrate-containing materials could be used as explosives, every effort should be made to keep them from people who are looking for materials to cause harm. Because of this, any building containing fertilizers should be protected by the appropriate locking system and should always be locked when the people who work at the site are gone. If fertilizer is stored outside, it is important to protect it with a fence provided with an effective lock.

Other Actions to Be Taken
Other actions that should be taken in a well-run fertilizer storage facility, which will tend to increase safety and reduce the number of accidents include:

• The site should have a high standard of housekeeping.
• Bags should be properly labeled, indicating the material contained.
• Install placards when nitrate materials are stored to make people aware of the hazards.
• Do not use hooks in handling bags. Besides being dangerous, they damage the bags, create spills, and expose the fertilizer to damaging moisture in the atmosphere.