Humidity Factors Affecting Storage and Handling of Fertilizers

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Abstract

The significance of the critical relative humidity (CRH) of fertilizer as related to handling and storage factors of the fertilizer is considered.

Values of CRH have been determined for a number of commercial nitrogen, phosphate, and potash fertilizers and their mixtures. These values are given and compared with values for pure fertilizer salts. The significance of CRH is considered in relation to moisture tolerance, compatibility of fertilizers, and the quality of packaging required for bagged products.

Methods of controlling moisture levels in buildings for storage of fertilizer in bulk are considered. The effect of heating upon relative humidity of the air is discussed; methods of calculation are outlined and a simplified graphical method shown.

Consideration is given to the design of fertilizer warehouses for bagged products, especially in the humid tropics. Particular attention is given to the need, if any, for ventilation. Although warehouses for bagged fertilizers must be capable of being ventilated, contrary to common practice such buildings should not be permanently ventilated. Humidity factors relating to these recommendations are discussed.
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Introduction

Most fertilizers contain water-soluble salts, which have been proven to be effective in supplying mineral nutrients to crops. All fertilizer materials are directly affected by water and can interact with moisture in the atmosphere, usually with such undesirable results as caking or physical breakdown. The property used as an indicator of the degree of likely interaction with atmospheric moisture is the critical relative humidity (CRH) of the fertilizer. This physical property has considerable significance when assessing the effect of moisture on fertilizer quality during handling and storage of fertilizers.

Values of CRH for pure fertilizer salts and their mixtures are available from the literature. Values for a range of commercial fertilizers and their mixtures have been determined experimentally and are discussed in the context of handling and storage properties.

Critical Relative Humidity of Fertilizers

CRH is the value of the relative humidity (RH) of the surrounding air, above which a fertilizer will absorb moisture and below which it does not absorb moisture. A high CRH is thus a desirable quality since fertilizers with high CRH values can be handled under more humid conditions without the undesirable consequences of moisture pickup.

For pure substances the CRH is marked by a distinct increase in moisture absorption at a particular point as the humidity level is increased. CRH values are thus well defined and reproducible and may also be calculated from published vapor pressure data for saturated solutions. Such values for some pure fertilizer salts are shown in Figure 1.

Commercial fertilizers are not pure substances; they contain widely varying quantities of impurities that lower the CRH value. The extent of the effect depends upon the source of the products or the raw materials used in their manufacture, as is particularly evident with potash and phosphate materials. The wide range of impurities present in samples of DAP prepared from wet-process phosphoric acid is shown in a recent TVA publication (1). Samples of the same

![Figure 1. Critical Relative Humidities of Pure Salts and Mixtures at 30°C (86°F).](image-url)
fertilizer from different sources will therefore exhibit different CRH values. The values obtained for pure substances can only be used as a general guide for commercial materials, and the CRH must then be determined for each particular product.

CRH values for some commercial fertilizer materials and mixtures are shown in Figure 2. These were determined by TVA using the "direct" test method (2). Comparison of Figures 1 and 2 shows very significant differences in CRH values between pure and commercial forms of phosphate and potash materials. Values for fertilizer products such as urea or ammonium nitrate, which are relatively pure chemicals, show much smaller differences:

<table>
<thead>
<tr>
<th>Pure salt</th>
<th>Urea</th>
<th>AN</th>
<th>MAP</th>
<th>DAP</th>
<th>KCl</th>
<th>K₂CO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>72.5</td>
<td>59.4</td>
<td>91.6</td>
<td>82.5</td>
<td>84.0</td>
<td>96.3</td>
<td></td>
</tr>
</tbody>
</table>

| Commercial fertilizer | 70 | 55 | 70 | 70 | 70 | 75 |

Comparison of CRH Values for Pure and Commercial Fertilizer Materials

Note: Determinations were made on commercial materials by TVA. CRH Values are approximate and may vary several points depending on production method and source of material.

Figure 2. Critical Relative Humidities of Commercial Fertilizers and of Mixtures at 30°C.
Effect of Temperature on CRH

CRH values are usually measured or calculated at 30°C. Values tend to decrease slightly with increase of temperature. For example, the CRH value of pure urea is 81% at 15°C and 73% at 30°C. For commercial urea, a relatively pure material, values are in the 70%-75% range at the temperatures encountered in tropical regions.

Moisture Tolerance of Fertilizers

CRH values are useful in indicating only the RH level at which moisture pickup will commence. Different fertilizer materials vary considerably both in the rate of moisture pickup and in their ability to tolerate the absorbed moisture. Further tests are necessary to evaluate the resulting changes in physical properties and effects upon properties. A range of tests is described in The Fertilizer Manual (2), including the determination of caking properties, granule strength, flowability, and the rate of penetration of moisture into a pile of bulk material.

The rate and extent of penetration of moisture into a bulk pile are of considerable importance. Comparative tests under standardized conditions give relative penetrations of 1.2 cm for DAP, 13.0 cm for urea prills, and 46.0 cm for ammonium nitrate prills (2). Some materials, such as urea, form a crust 10-15 cm thick in bulk piles after several days of exposure to conditions of high humidity. This appears to give protection to the material underneath the crust. It is interesting to note that neither the rate of moisture absorption nor the depth of moisture penetration correlates with CRH (2).

Incompatibility of Fertilizers

Mixtures of fertilizers generally have lower CRH values than do the individual components, which means that more care must be taken during handling to protect such mixtures from moisture pickup. This effect is so marked in the case of urea and ammonium nitrate that the materials should be considered totally incompatible and should not be handled in the same equipment and, if possible, not stored in the same building. This also applies to their compounds and mixtures.

A specific incompatibility arises from the chemical reaction between urea and monocalcium phosphate, which is the principal constituent of superphosphates (SSP & TSP). The reaction releases chemically bound water; this causes caking or wetting of the mixture. As demonstrated in work carried out by TVA, however, the reactivity of TSP with urea does vary considerably, depending on the manufacturing source of the TSP (3). Mixtures of urea with TSP from certain sources can be used in bulk blends when the blend is applied relatively soon after mixing. It is not advisable to blend urea and any TSP or SSP when the mixture is to be stored for any length of time, whether in bags or in bulk.

Bagged Fertilizer Moisture Protection

Fertilizer bags generally have a strong outer bag to contain the product during handling and an inner liner of fairly light-gauge polyethylene (3 or 4 mil) to act as a vapor barrier and to prevent sifting or loss of product. The polyethylene layer is not completely waterproof, as is often assumed; it has some permeability to water vapor. The driving force for the passage of water vapor is proportional to the difference between the atmospheric humidity and the CRH of the fertilizer so that products of low CRH are more likely to give problems in prolonged storage unless packaged in more resistant (and higher cost) materials. Fertilizers of low CRH, such as ammonium nitrate, require a heavier gauge liner, and particular attention must be paid to proper sealing or closure of the liner. Fertilizers of high CRH, such as TSP, are sometimes packed in bags without a polyethylene liner or other vapor barrier.

Bulk Fertilizer Storage

For fertilizers stored in bulk, a completely closed building is required for protection against atmospheric humidity. This is generally impractical. Control of the relative humidity of the air in the building at or below the CRH of the fertilizer is then necessary, and this is usually achieved by one or more of the following three methods.
Examples of well-constructed warehousing with built-in permanent ventilation— not recommended for long-term storage of fertilizers in the tropics.
Investigation of deterioration in storage, including consideration of product characteristics, package specifications, and warehousing conditions.

Ammonium Nitrate; CRH 59%

24 hours at 55% RH  24 hours at 65% RH

Demonstrating the need for protection from atmospheric humidity.
1. Refrigeration or Air Conditioning

This method condenses some of the moisture from the air, but the cooling effect raises the relative humidity (RH) of the air in the building. If heat input from solar gain and product heat is not sufficient to restore the temperature to a point where the RH of the air is below the CRH of the fertilizer, the product will still absorb moisture. Reheating of the refrigerated air may then be necessary.

2. Dehumidification

The air may be dried with chemical dehumidification agents, liquid or solid, in absorption towers. The drying agents are then regenerated in a separate cycle, usually by heating.

3. Heating

Heating of the air in the building lowers its relative humidity without affecting the absolute water content, i.e., without removing any of the moisture in the air. It is, however, the relative humidity of the air in relation to the critical humidity of the fertilizer that determines moisture absorption by the fertilizer. Thus, the method is effective, even under tropical conditions.

In order to calculate the level of heating required, psychrometric tables may be used, although these are rather difficult to understand and to interpret without error. Calculations can also be made by using basic data for the mass of water vapor contained in saturated air at various temperatures. Values are given in Table 1. As an example, assume that the ambient air is at 25°C and 95% relative humidity, and we wish to lower the RH of the air for storage of urea (CRH 70%) to 65% by heating. The method of calculation is as follows.

- Water content of saturated air at 25°C 22.80 g/m³
- Water content at 95% RH 21.66 g/m³

This represents 65% (required RH) of 33.32 g/m³ is saturation value for air at 31.9°C

In order to lower the RH of the air from 95% to 65%, it is therefore necessary to heat it by 6.9°C, from 25° to 31.9°.

To facilitate such calculations, a simplified relationship has been developed, and this is shown graphically in Figure 3. Using the example given above, we wish to lower the RH from 95% to 65%, which is 30 in 95, a factor of 0.32. This corresponds on the graph to a temperature rise of 7°C, which agrees closely with the calculated value of 6.9°C. The level of accuracy obtained by using the graph is considered quite adequate for calculations involving these systems.

Heating of the air in a building for RH control purposes may increase the temperature to levels that are unacceptable for operators working in the building, although the resulting lower RH may improve the comfort factor. One fairly common way of overcoming this problem is to use a system combining refrigeration (hence moisture removal) with some reheating of the air.

Where moisture-related problems are encountered in storage and handling of fertilizers, it is necessary to determine the physical properties of the particular materials being handled and then to undertake a series of determinations of the humidities encountered under actual operating and storage conditions.

Table 1.

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>0.0</th>
<th>1.0</th>
<th>2.0</th>
<th>3.0</th>
<th>4.0</th>
<th>5.0</th>
<th>6.0</th>
<th>7.0</th>
<th>8.0</th>
<th>9.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20</td>
<td>0.892</td>
<td>0.810</td>
<td>0.737</td>
<td>0.673</td>
<td>0.613</td>
<td>0.557</td>
<td>0.505</td>
<td>0.457</td>
<td>0.413</td>
<td>0.373</td>
</tr>
<tr>
<td>-10</td>
<td>2.154</td>
<td>1.978</td>
<td>1.811</td>
<td>1.658</td>
<td>1.519</td>
<td>1.395</td>
<td>1.282</td>
<td>1.177</td>
<td>1.079</td>
<td>0.982</td>
</tr>
<tr>
<td>0</td>
<td>4.365</td>
<td>4.468</td>
<td>4.130</td>
<td>3.813</td>
<td>3.518</td>
<td>3.244</td>
<td>2.988</td>
<td>2.752</td>
<td>2.537</td>
<td>2.340</td>
</tr>
</tbody>
</table>

Source: Smithsonian tables.

Bagged Fertilizer Storage

There is a widespread and often unquestioned belief that warehouses for storage of bagged fertilizers should be freely ventilated. From consideration of the CRH and humidity effects discussed above, it is evident that the opposite approach is more likely to be required. On technical grounds there is no reason why a store for bagged fertilizer should be...
treated any differently from a store for bulk fertilizer; unfortunately, such a distinction is often made.

In the tropics, humidities that are moderate to high in the daytime increase to very high levels during the night when temperatures are lower. Some data from Bangladesh show that ambient humidity levels are above the CRH level of urea during the night throughout the entire year and during the day for 6 months of the year. Although the fertilizer is given substantial protection by the package, it is clearly inadvisable to ventilate the store freely at all times, especially during the night when the air is highly humid.

It can then be recommended that properly designed warehouses for bagged fertilizer not be permanently ventilated, particularly where long-term storage is involved. When humidity levels are high, the warehouses should be kept as tightly closed as possible, like those for bulk storage, and this applies particularly during the night. Because of the need for operating access to the warehouse during daytime hours, entry of ambient air is inevitable. During periods of high humidity, entry of such humid air should, however, be minimized. During periods of low humidity, essentially when the weather is sunny and dry, ventilation should be maximized. This means that doors, windows, and ventilators should be opened and, if available, extraction fans or mechanical ventilation can be used. With the setting of the sun, the warehouse should be closed up and kept as airtight as possible.

The foregoing reasoning may not apply to older buildings that may not have a damp-proof course in the floor or walls; without this barrier ground water can rise and create very high relative humidity levels of the air in the building, possibly approaching saturation value for much of the time. In such cases, the criterion to be applied is that the building should be ventilated whenever the internal RH is greater than the RH of the exterior ambient air. The RH of the ambient air may still be above the CRH of the fertilizer, but ventilation to remove the saturated air in the building is the lesser of two evils. The right approach in such a situation is to correct the structural deficiency and prevent entry of moisture by waterproofing of the floor and walls.
References

