Physical and Chemical Properties of Fertilizers and Methods for their Determination

Introduction

The physical form in which a fertilizer is produced is of considerable importance, both agronomically and in regard to satisfactory handling, transport, storage, and finally application to the field. Most of the problems encountered with fertilizers probably are those resulting from deficiencies in physical properties; frequent problems include caking, dustiness, poor flowability, segregation, and excessive hygroscopicity. Customer acceptance or preference for a particular fertilizer over another of equal plant-food content is almost always based on physical properties of the product. Good physical condition, which is relatively easy for the customer to evaluate by simple observation, ensures him of easier, faster, more uniform, and less expensive application to the field. Also, in the various handling, transport, and storage steps that usually are involved between production and final use of fertilizers, it is essential that physical properties be such that the material remains free flowing (noncaking), that it be relatively nondusty, and that it withstand a reasonable amount of exposure to normal atmospheric humidity. Many production techniques, including various physical "conditioning" treatments, have been developed especially to provide favorable physical properties.

Physical properties of fertilizers, unlike the chemical compositions, normally are not governed in commerce by laws. Physical condition usually is a matter only of private agreement between purchaser and supplier. As a result, there are few "official" methods for measurement and evaluation of physical properties. Various producers tend to adopt or develop methods that appear to best suit their particular needs. However, some government-sponsored research organizations such as the U.S. Department of Agriculture and the Tennessee Valley Authority in the United States have developed and published procedures intended for general application to a variety of fertilizers; references to these procedures are included in this chapter. Also, the International Standards Organization, Technical Committee 134/SC3, is actively engaged in efforts to establish international standard methods for measurement of various physical properties of fertilizers (1).

The present chapter includes brief discussions of the effects and importance of various pertinent physical properties of fertilizers and descriptions of some of the methods that have been used and reported for measuring these properties. Some of the chemical properties that affect the reaction of fertilizers in the soil are also discussed in this chapter. Numerous literature references are given from which details of test procedures usually can be obtained.

Particle Size

Measurement of particle size is an important physical test that is routinely applied to fertilizer materials almost as frequently as is chemical analysis; almost all producers are equipped to check particle size regularly. The importance of particle-size control varies with the type of product, the intended method of handling, and the final use. Some of the reasons for size control follow.

Effects on Agronomic Response

Fertilizer materials of very low water solubility generally must be ground to small particle size to ensure sufficiently rapid dissolution in the soil and utilization by plants. For example, the effectiveness of raw phosphate rocks generally increases with fine grinding down to a particle diameter of about 0.15 mm; below that, little further benefit has been established (2). Other materials of low solubility that require relatively fine grinding include basic slags, limestone, dolomite, dicalcium phosphate, and fused phosphates such as calcium-magnesium phosphates, defluorinated phosphate rock, and calcium metaphosphates. Micronutrient or secondary nutrient sources of low solubility, such as sulfur, metallic oxides, and glasses ("frits"), likewise require fine grinding.

The fine grinding required for these materials often results in undesirable dustiness and other handling difficulties. Therefore, some research and development has been directed toward regranulating the pulverized materials, especially rock phosphate, with soluble binders to give granules that will handle well and then revert to pulverulent form in moist soil (2, 3, 4). Phosphate rock granules of relatively small size (0.1-0.3 mm), sometimes referred to as "mini-granules," have in some tests been more effective than larger granules in this application (5, 6). Methods of dust control other than granulation include spraying the pulverized materials lightly with oil, water, or amine formulations. In the case of granular nitric phosphates, which normally contain phosphate in water-insoluble form as dicalcium phosphate or apatite, the crystal size of these materials is usually quite small, and there are sufficient water-soluble salts in the granule to ensure disintegration of the granule in moist soil with resultant increase in soil-phosphate contact. In such products, however, it has been considered desirable to have a reasonable proportion of the phosphorus in water-soluble form to ensure early response of crops (7, 8, 9).

Particle-size control of water-soluble fertilizers usually is for reasons other than agronomic ones, as
will be discussed later. However, there apparently can be agronomic benefits also. For example, it has been found that in the application of water-soluble phosphates such as superphosphates and ammonium phosphates, especially to acid soils of high phosphate-fixation capacity, an increase in the rate of nitrogen availability from these materials, has been shown to be dependent on particle size; the larger the particles, the slower the release.

Another potentially useful application of particle-size control for improvement of agronomic properties is in connection with some sparsely soluble slow-release nitrogen fertilizers such as urea-formaldehyde, isobutyldiurea, and oxamide. The rate of dissolution and hence the rate of nitrogen availability from these materials, has been shown to be dependent on particle size; the larger the particles, the slower the release.

Effects on Storage and Handling Properties

Particle-size control of fertilizers is important to ensure satisfactory storage and handling properties. Before about 1950 almost all fertilizer materials were produced as relatively fine powders or small crystals. As a result, fertilizers usually were dusty in handling and very susceptible to hard caking during storage in piles or bags. Considerable labor usually was required to break up the lumps and make the products suitable for field application. The rapid growth of granulation in the early fifties, however, resulted in great improvement in storage and handling properties. This growth of granulation was paralleled by improvements in application equipment that took advantage of the better flow properties and absence of caking in granular products. Farmer demand for the granular products and for the improved application equipment soon was overwhelming. In the United States, the generally accepted nominal particle-size range for granular materials became 1.00-3.35 mm which represents material that will pass a U.S. Standard No. 6 screen but be retained by a No. 18 screen. There are, however, no state or federal regulations in the United States that specify allowable size or size tolerances for granular products; control is left to individual producers. The U.S. Agency for International Development (USAID), in purchasing granular fertilizers for its aid programs, generally specifies 90% minimum in the 1.00- to 3.35-mm (U.S. 6- to 18-mesh) range, 0% larger than 4.75 mm (U.S. 4-mesh), and no more than 2% finer than 0.6 mm (U.S. 30-mesh) (11).

In European countries and Japan, granular fertilizers generally are produced in somewhat larger particle sizes; sizes reported are generally in the range of 2.0- to 4.0-mm diameter (U.S. 5- to 10-mesh) (12, 13, 14, 15, 16).

Fertilizers preferably should be free from particles so small that they generate air-borne dust on handling, both to ensure farmer acceptance and to prevent unpleasant or unhealthy working conditions in areas such as bulk-blending plants or bulk-handling operations. A frequent cause of dustiness in granular fertilizers is poor adherence of powdery conditioners (coating agents). The test methods for determining dustiness due to that cause will be described in a subsequent section of this chapter. The method can be adapted to measure dustiness resulting from any cause such as attrition during handling.

Granules of especially large size (> about 4 mm) have been found to be desirable for aerial application to forests. The large size minimizes wind drift and reduces lodging of granules in tree branches. In several countries there is either commercial or experimental production of "forestry-grade" urea or ammonium nitrate of large size for this purpose.

Effects on Blending Properties

Since the advent (about 1958) of bulk blending as an important system of mixing and distributing granular fertilizers, control of particle size has assumed additional importance as a method for reducing the segregation tendency of blends. The practice of bulk blending is described in UNIDO publication, Monograph No. 8 (Fertilizer Industry Series, ID/SER.F18) titled "A Fertilizer Bulk Blending and Bagging Plant," and in less detail in chapter XIX.

In some early blending operations, materials were blended without regard to matching of particle sizes, with the result that the blends were very susceptible to segregation (unmixing) during handling. Subsequent studies by TVA and others identified particle-size matching of blend ingredients as by far the most important factor in producing a blend that is resistant to segregation (17, 18, 19, 20, 21). The effects of mismatches in other physical properties, namely density and particle shape, were insignificant in comparison with the effect of mismatch in the particle size.

The general size range of 1.00 to 3.35 mm (minus 6- plus 18-mesh, U.S. Standard) which defines granular fertilizer in the United States is not sufficiently restrictive to ensure good size matching for bulk blending. It has been found that materials for blending should agree not only in regard to their upper and lower size limits but should also be reasonably similar in particle-size distribution between these limits (17, 19). Agreement of size distribution curves within plus or minus 10 percentage points has been suggested as an effective criterion (18). The effects of adherence and nonadherence to this criterion are shown in figure 1. In the tests illustrated, granular ammonium phosphate of typical particle-size distribution was used in two bulk blends, one with a potash ("granular" grade) of very similar particle-size distribution (12 percentage points maximum divergence of size distribution curves) and another with much finer potash ("coarse" grade; 57 percentage points divergence). Each blend was poured to form a sloped pile in a small plastic view box (see later section on segregation tests). From the figure, it is obvious that during the pouring operation there was serious segregation in the blend of unequally sized materials but little obvious segregation in the blend of matched sizes.

![Figure 1. Particle-Size Matching Decreases the Segregation Tendency of Bulk-Blend Fertilizers (19).](image-url)