

Triple Superphosphate Crops

Executive Summary

Triple superphosphate is a synthetic phosphorous fertilizer and appears to be categorically prohibited as such by OFPA [7 USC 6508(b)]. TAP Reviewers were unanimous in their finding that the substance was synthetic, that the petitioned uses are incompatible with organic principles, that alternatives exist, and that the substance should not be added to the National List of Allowed Synthetics.

Identification

Chemical Name:

concentrated superphosphate (the term monocalcium phosphate is technically only for food and feed grade)

CAS Number: 65996-95-4

(8011-76-5 is ordinary superphosphate and 7758-23-8 is food and feed grade monocalcium phosphate)

Other Generic Name:

triple (or treble) superphosphate

Other Codes: none found

Trade Names: 0-45-0; 0-46-0; 0-50-0; TSP

Summary of TAP Reviewer Analysis ¹

Synthetic / Non-Synthetic:	Allowed or Prohibited:	Suggested Annotation:
<i>Synthetic (3-0)</i>	<i>Prohibited (3-0)</i>	<i>None</i>

Characterization

Composition: Concentrated superphosphate is composed predominately of monocalcium phosphate hydrate ($\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$) and generally contains 43-50% P_2O_5 (Budavari, 1996). This is distinguished from both ordinary superphosphate and food- or feed-grade monocalcium phosphate such as mono-, di- and tri-basic calcium phosphates. Ordinary superphosphate contains approximately 30% $\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$ with the remaining composed of approximately: 45% gypsum by-product; 10% calcium biphosphate (CaHPO_4); 10% iron oxide, silica, and aluminum; and 5% water (Budavari, 1996).

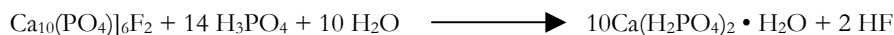
Properties: Large, shining triclinic plates; crystalline powder; or granules (Budavari, 1996).

How Made: Superphosphates can be either ordinary or triple, depending on the phosphate (P_2O_5) content. Ordinary superphosphate is produced by the reaction of a rock phosphate with sulfuric acid (H_2SO_4). This can be theoretically characterized as (Tisdale and Nelson, 1966):



yielding a product that contains between 18-20% P_2O_5 (Maynard and Hochmuth, 1997).

The petition addresses triple superphosphate specifically by CAS #65996-95-4. The production of triple superphosphate from raw apatite ore involves a complex series of reactions. These all involve phosphoric acid, and may or may not also use sulfuric acid. Monocalcium phosphate is only one of the products of the process. Theoretically, triple superphosphate is made by the reaction of fluorapatite with phosphoric acid in aqueous solution (Hoffmeister, 1993):



¹ This Technical Advisory Panel (TAP) review is based on the information available as of the date of this review. This review addresses the requirements of the Organic Foods Production Act (OFPA) to the best of the investigator's ability, and has been reviewed by experts on the TAP. The substance is evaluated against the criteria found in section 2119(m) of the OFPA [7 USC 6517(m)]. The information and advice presented to the NOSB is based on the technical evaluation against that criteria, and does not incorporate commercial availability, socio-economic impact or other factors that the NOSB and the USDA may want to consider in making decisions.

This is a simplification of the actual manufacturing process (Follett, Murphy, and Donahue, 1981). Actual production methods vary, and usually involve a number of different reaction steps (Górecki, 1994). One of the most widely used manufacturing processes is the Dorr-Oliver process (Hoffmeister, 1993; Górecki, 1994) also known as the granular TSP method (US EPA 1999b), with another method developed by the US Department of Agriculture and the Tennessee Valley Authority (TVA) accounting for much historical production (Philips and Webb, 1971). This other method is known in the industry as run-of-the-pile (ROP-TSP) (US EPA 1999b). Both of these methods are “wet process phosphoric acid” such as the petition describes. The basic chemical reactions are the same, with the main differences being in the physical handling and processing. Another process involves the reaction of limestone with phosphoric acid (Bierman and Long, 1978).

Sources of tricalcium phosphate, one of the ingredients in the superphosphates, include mined rock phosphate such as apatite ores (fluorapatite and oxyapatite), voelicherite, and whitlockite. Tricalcium phosphate can also be recovered from bones and bone meal; the petition specifically lists “monocalcium phosphate, a salt derived from rock phosphate.”

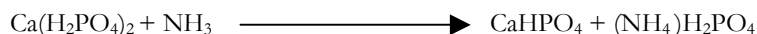
Some references used for this review refer to “superphosphate” in the singular form and do not distinguish between ordinary and triple. These are listed in this document as superphosphate. When the superphosphates (plural) is used, this refers to both ordinary and triple forms.

While fertilizer grade triple superphosphate is made from direct acidulation of rock phosphate, the impurity levels are generally too high for other applications. Monocalcium phosphate used for baking powder (CAS # 7758-23-8, different than this petitioned material for crops use) is crystallized from a reaction mixture of concentrated phosphoric acid and lime, or by spray-drying a slurry of the product of a reaction of lime and phosphoric acid (Petersen and Freilich, 1992).

Specific Uses: The chief uses of superphosphates include as phosphate fertilizers, for enameling, and in construction material. Food and feed grade monocalcium phosphate (CAS # 7758-23-8) is used as an acidulant in baking powders and as a mineral supplement for various foods and livestock feed.

Action: Superphosphates are applied to soil and used in fertilizer as a source of plant available phosphate (Baker, 1925; Karrabaker et al., 1941; Collings, 1950; Tisdale and Nelson, 1966).

Specific to the petition, the monocalcium phosphate in the triple superphosphate reacts with the ammonia in manure by the following reaction (from Midgley and Weiser, 1937):



Superphosphates are also acidifying, and may be used to lower the pH of soils and transplant media (Parnes, 1990). Phosphorus precipitates in the form of various calcium phosphate compounds at higher pHs (Bohn, et al., 1979; 1985).

Combinations: Monocalcium phosphate is the primary component of both ordinary and triple superphosphate. Ordinary superphosphate contains a certain amount of by-product gypsum from the reaction. Commercial ordinary and triple superphosphate can be blended with a wide range of materials, including compost (Rynk, et al., 1992). Many superphosphates are enriched with ammonia (Tisdale and Nelson, 1966). (Point of clarification from the investigator: After considering information provided by the petitioner and the reviewers, it appears that many of the empirical studies cited here that document superphosphate’s ability to stabilize ammonia were conducted on manure rather than on compost. In compiling the TAP review, where possible we sought to make clear the medium that was receiving either the superphosphate treatment or one of the alternatives.)

Status

Historic Use by Organic Growers: The use in organic farming systems has long been discussed (Parnes, 1990). However, superphosphates are generally not used by certified organic farmers. See below under “Status Among U.S. Certifiers” for some historical exceptions.

OFPA, USDA Final Rule:

Prohibited as a synthetic phosphate fertilizer under OFPA, 7 USC 6508(b)(1). The petition is to use triple superphosphate as an ingredient to make compost [see Final Rule 7 CFR 205.105(a), 205.203(e)(1), and 205.601(c)].

As the petition notes, the NOP Final Rule allows phosphoric acid to be used for certain specific uses and applications. Phosphoric acid is allowed to be used to adjust the pH in liquid fish fertilizers provided the amount of acid used does not

exceed the minimum to lower the pH to 3.5 [205.601(j)(7)]. Phosphoric acid is also allowed to clean equipment cleaner used in livestock production and in processing [205.603(a)(13) and 205.605(b)(22)]. No other uses are listed.

Food grade mono-, di-, and tri-basic calcium phosphate appear on the National List for use as a minor ingredient in dairy products [7 CFR 205.605(b)(7)]. Also, FDA approved feed grade calcium phosphates may be permitted as feed additives used for enrichment or fortification [7 CFR 205.603(d)(1)]. As discussed above, food and feed grade calcium phosphates are not identical to fertilizer grade superphosphates.

Regulatory: EPA/NIEHS/Other Sources

EPA – The EPA does not regulate monocalcium phosphate, ordinary superphosphate or triple superphosphate as a hazardous substance. Phosphoric acid was removed from EPA's Toxic Release Inventory (TRI) list in 1999 based on a ruling by the US District Court for the District of Columbia (Jasinski, 1999). EPA limits radon emissions from phosphogypsum (fertilizer phosphorous and by-product gypsum) stacks (US EPA 1999a). Hydrogen fluoride emissions from phosphoric acid and phosphate fertilizer factories are also regulated by EPA (US EPA 1999a).

NIEHS – The National Toxicology Program (NTP) does not have a monograph on monocalcium phosphate or any form of superphosphate.

Other Sources – The Association of American Plant Food Control Officials' (AAPFCO) various state officials regulate superphosphates as plant foods. Superphosphate is obtained when rock phosphate is treated with either sulfuric acid or phosphoric acid, or with a mixture of those two acids (AAPFCO, 2000).

Status Among U.S. Certifiers

Prohibited by all U.S. certifiers except Maine Organic Farmers and Gardeners Association (MOFGA). MOFGA has historically allowed it for use as a compost ingredient only for use in potting media. MOFGA prohibits field application of such compost. The MOFGA standards list as permitted, “ B.5.: transplants raised in a so-called ‘organic’ potting mix containing compost that has superphosphate or iron sulfate added to stabilize nitrogen during composting process.” The standards then state “Potting mixes made with compost described above in B.5. will not be permitted after the 2001 growing season” (MOFGA, 2001).

The petition states an allowance for the petitioner's compost and greenhouse mix, “...New Hampshire NOFA, where a state-run review continued to allow both” (Ramsey, 2000). The New Hampshire Department of Agriculture lists superphosphate as prohibited [NH Agricultural Administrative Rule 906.04(c)(5)(f)]. This extends to both ordinary (normal) superphosphate and triple superphosphate, both field applied and as a compost feedstock (Uncles, 2001). NOFA-New Hampshire is a grower group and does not conduct an organic farm certification program.

International

CODEX – Prohibited since not explicitly listed as allowed.

EU 2092/91 – Prohibited since not explicitly listed as allowed.

IFOAM – Prohibited since not explicitly listed as allowed.

Canada – Prohibited since not explicitly listed as allowed.

Japan – Prohibited since not explicitly listed as allowed (from the unofficial English translation).

Other International Certifiers – None known of outside the US that allow superphosphates in crop production.

Section 2119 OFPA U.S.C. 6518(m)(1-7) Criteria

1. *The potential of the substance for detrimental chemical interactions with other materials used in organic farming systems.*

In general, most of the literature considers the interaction between compost and superphosphate to be beneficial rather than detrimental, in that organic matter maintains superphosphate in solution. One composting guide states that superphosphate conserves nitrogen in dairy manure during composting (Rynk, et al., 1992). This conserves ammonia nitrogen in the compost, stimulates phosphate uptake, and provides a production response. This includes composts used in potting soil (Bunt, 1976). [Note that in this and other references, particularly those that use British English, the word ‘compost’ is sometimes used to refer to generic potting soil that does not necessarily include compost as defined by the NOP Final Rule.]

Combinations with many nitrate-based fertilizers can be highly volatile. The most serious potential detrimental interaction is with sodium (Chilean) nitrate in wet conditions. Early efforts to produce a balanced fertilizer by mixing sodium nitrate and superphosphates resulted in an unstable mixture (Collings, 1950).

Potentially a much more common detrimental interaction would be nutrient tie-up from incompatible blending or excessive application. While soluble, superphosphate rapidly becomes fixed to soil particles (Baker, 1925). The primary interactions in the soil are free H_2PO_4^- , HPO_4^{2-} and PO_4^{3-} anions with available cations. The reactions are based on available cations and soil pH, with the following preference in binding to cations observed as pH rises: iron > aluminum > calcium = magnesium > sodium (Follett, Murphy, and Donahue, 1981). Thus, depending on pH and other conditions, limestone, dolomite, and iron could be tied up from a phosphate excess or incompatible mixing. Other essential micronutrients may also be tied up by phosphorous. For example, a heavy application of phosphate could induce a zinc deficiency (Ludwick, et al., 1990).

The enhanced solubility of superphosphates can be considered detrimental. Superphosphates become more mobile with management techniques common to organic production. Despite being fixed in most situations, over a longer time period, superphosphates will leach to a certain extent. Factors that increase the rate of leaching are related to soil management. The rate at which phosphate is fixed or conversely how much it will leach depends most on available iron, aluminum, magnesium, soil organic matter, and the activity of soil microorganisms (Brady, 1974). One experiment showed fields that received farmyard manure and superphosphate had twice as much soluble phosphate in the subsoils as fields that received farmyard manure alone (Warren and Johnston, 1961, cited in Cooke and Williams, 1973). It is not clear if this was because organic matter maintained superphosphate in solution longer or simply because the phosphate levels were higher in the superphosphate treated fields.

Also, in organic compost based potting mixes, ammoniacal nitrogen ($\text{NH}_4\text{-N}$) is high relative to nitrate nitrogen ($\text{NO}_3\text{-N}$) (Brinton and Tresemer, 1988). By maintaining nitrogen in ammoniacal form, the addition of triple superphosphate may exacerbate this imbalance. As noted below (5) superphosphates can depress the levels of vesicular-arbuscular mycorrhizae (VAM). Various inoculants used contain VAM. One TAP reviewer found an article and an unpublished paper that supported the benefits of phosphate fertilization to earthworms, but the studies did not describe the sources of phosphorous or the research methods adequately.

2. *The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.*

Monocalcium phosphate itself is considered generally non-toxic (Ramsey, 2000). Fertilizer-grade triple superphosphate will form free acids and can release fluorides (IMC, 1988). The mobility and fixity of soluble phosphate is a long-studied subject. Persistence of phosphate is generally not considered a problem, except when excessive amounts tie up other nutrients. As noted above, soluble phosphate has long been considered fixed to soil particles after a relatively short period of time. Superphosphates will generally adsorb to clay and react with cations in the soil depending on pH, cation exchange capacity, and available cations. Leaching of soluble, or runoff of, phosphate fertilizer bound to eroding soil is a source of phosphate in rivers, lakes, and streams, although the amount and significance of the contribution of fertilizer sources is questionable (Cooke and Williams, 1973). Empirical evidence supports that soluble fertilizer runoff and excessive phosphate fertilization contributes to overall water pollution caused by erosive and intensive soil management practices (National Research Council, 1989).

3. *The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.*

The superphosphates manufacturing processes generate air pollution (US EPA, 1999b), an effluent stream (Górecki, 1994), solid waste that can contain high levels of toxic heavy metals (EPA, 1999a), and radioactive waste (Bunus, 1994; EPA, 1994) that can potentially include hazardous components (EPA, 1999a). Acidulation of apatite produces hydrofluoric acid (HF), a very strong acid that is highly reactive (Górecki, 1994). Liquid or vapor HF causes severe irritation of the eyes and eyelids and may result in prolonged or permanent visual defects or total destruction of the eyes. Skin contact may result in painful burns. Inhalation of HF results in extreme irritation of the respiratory tract, pulmonary inflammation, and congestion. HF ingestion results in necrosis of the esophagus and stomach with nausea, diarrhea, vomiting, circulatory collapse, and death (Budavari, 1996). The technology to remove and recover fluoride from the HF in both single and triple superphosphate manufacturing has made great strides since the 1950s but has not been installed in all manufacturing plants and still can be improved (Górecki, 1994).

Phosphate fertilizers are known to contain varying levels of heavy metals such as cadmium, lead, nickel, and chromium (Charter et al., 1993; Mortvedt, 1987). These metals may originate in the phosphate rock (Mortvedt and Giordano, 1977). The cadmium and other metals remain with the phosphate during processing (Wakefield, 1980, cited in Center for Environmental Analysis, 1999). Other contaminants produced from the manufacturing process include arsenic, cadmium, and lead. All of these heavy metals are naturally occurring in the ore.

Certain sources of rock phosphate, and the phosphoric acid and triple superphosphate from which they are derived, are also radioactive from contamination with uranium as ^{238}U , thorium as ^{232}Th , and radon as ^{226}Rn (Bunus, 1994). Some forms of processing can remove the radioactive isotopes; other processing methods will concentrate the isotopes in the fertilizer (Bunus, 1994).

4. *The effects of the substance on human health.*

Calcium and phosphate are both essential nutrients important for bone formation, metabolic function, and other biological processes. The active calcium phosphate is not considered a human health risk. However, elemental contamination of triple superphosphate with arsenic, cadmium, fluorine, and lead may be potential risks to human health (US EPA, 1999b). The presence of radionuclides in superphosphates may also pose a human health risk (US EPA, 1999).

5. *The effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops and livestock.*

The water solubility of phosphate fertilizers is highly variable (Phillips and Webb, 1971). Superphosphates are more soluble than tricalcium phosphate from either rock phosphate or bone meal. The concentrated solution that moves from triple superphosphate is very acid—the pH is approximately 1.5—and dissolves Fe, Al, Mn, and Ca from the soil to form precipitates of varying solubility (Phillips and Webb, 1971). Solubility is also influenced by the other ingredients and the particle size. Smaller particles are more soluble; larger particles are less soluble.

The salt index is 10.1 (Rader, Whittaker, and White, 1943; Meister, 2001). Solubility of triple superphosphate is 1.8 at 30°C (Meister, 2001). Superphosphate used in transplant media has been shown to leach from the containers at a rate proportional to the amount used (Nelson, 1990); particle size, air space (Yeager and Barrett, 1984); and time the plants are in pots (Yeager and Barrett, 1985). None of the studies cited used compost as described in the petition.

Vesicular-arbuscular mycorrhizae (VAM) are symbiotic with plants and help to cycle relatively insoluble nutrients, including phosphate. VAM have been shown to increase the availability of relatively insoluble nutrients in the soil, in particular phosphorous, copper, and zinc. Superphosphate fertilizer has been shown to suppress VAM (Amijee, et al, 1989; Vivekanandan and Fixen, 1991) and decrease the length of root that is colonized (Thomson, et al., 1992). VAM suppression has been documented at relatively low rates of application of P-fertilizer (Clapperton, Janzen, and Johnston, 1997).

6. *The alternatives to using the substance in terms of practices or other available materials.*

The petition states that for adjusting pH in compost, “The only other material which could be used and is currently on the National List for crop production, is iron sulfate.” Iron sulfate does not appear under compost feedstocks [205.601(c)]. Iron sulfate can be considered a micronutrient on the National List of allowed substances [205.601(6)(ii)]. The annotation requires that to apply the substance, the operator must document a soil deficiency by testing.

The investigator and reviewers discovered a number of materials and management practices that have historically and are currently used as alternatives to triple superphosphate for this purpose. These include: lowering or the pH by the use of natural substances; addition of carbon; efficient compost pile management; and the timing of compost or manure application. Various non-synthetic substances can be used to buffer or lower the pH of compost.. Sources allowed under the NOP Final Rule include bone meal, animal manures with a relatively high phosphorous content (e.g., poultry manure) (Parnes, 1990), compost, and rock phosphate (Lampkin, 1990; Parnes, 1990). In general, commonly mixed organic materials will usually create a balanced pH in the optimum range of 6.5-8.0 in a properly made compost (Rynk, et al., 1992).

Considerable research has been done on conservation of ammonia in manure, with most experiments conducted in the first half of the 20th century. Most of these studies did not involve compost made according to NOP Final Rule standards. Highly alkali compost—for example where horse manure is a feedstock—can be buffered by the addition of gypsum or peat, but the ammonia preservation and reduction of volatilization appears relatively poor when compared with superphosphates (Collison and Conn, 1922). The addition of rock phosphate and various clays will help to reduce ammonia volatilization during the composting process (van Horn, 1995).

Management techniques can make a significant difference in controlling ammonia losses. Proper composting can stabilize and conserve ammoniacal nitrogen ($\text{NH}_4\text{-N}$) (Sheppard, Phillips, and Bhogal, 2000). In-vessel composting and less frequent turning of aerobic compost can conserve ammonia (van Horn, 1995). Timing, waiting for warmer soil temperatures, and rapid incorporation into the soil can also reduce ammonia losses (Heck, 1931). Water

management and recycling leachate can conserve nitrogen during the composting process (van Horn, 1995). Liquid manure experiences greater ammonia loss than a manure that is bulked or dried (Heck, 1931).

High ammonia losses are generally correlated with a carbon:nitrogen (C:N) ratio that is sub-optimal. Ammonia can be conserved through the addition of carbon to raise the C:N ratio (Rynk, et al., 1992). Carbon sources that produce organic acids, including humic acid can also lower pH and conserve ammonia. Fruit pomaces, sawdust, and other plant-derived feedstocks can help to balance the pH of a well-prepared compost. An earlier bulletin from the University of Massachusetts experiment station supports the efficacy of superphosphate but does not consider rock phosphates (Lindsay, 1912). Elemental sulfur can also lower pH (Tisdale et al., 1985). Sulfur appears on the National List of allowed synthetic substances for fertilization [205.601(j)(2)], but not as a compost feedstock [205.601(c)]. Non-synthetic sources of sulfur exist, although the last sulfur mine in the US closed in 1999 (Ober, 1999).

Ammonia nitrogen can be conserved by increasing the C:N ratio. The addition of straw is useful in ammonia conservation when gathering and storing raw manure (Yusok and Bear, 1943). The increased carbon increases microbial growth which consumes nitrogen at the same time (Brady, 1974). Ammonia loss is highly correlated with pH. Free ammonia increases from 1% to 10% as pH increases from 7 to 8 (Tisdale et al., 1985). The carbon:phosphorus (C:P) ratio can significantly influence biological degradation where the C:N ratio is 30:1 or greater. Some municipal solid waste (MSW) compost is composed primarily of paper and has very low nitrogen and phosphorus contents. In this context the C:N and C:P of MSW with an initial C:N ratio of 53:1 was modified with TSP and ammonium nitrate to achieve C:N from 53:1 to 30:1 and C:P ratios of 500:1 to 60:1. The treatments were composted for four weeks. Increasing the C:P ratio increased soluble N in this high carbon environment (Brown et al., 1998). This composting environment is different from composting manure or another feedstock with a high N content. One study compared ammonia emissions from food waste, yard waste, and MSW composting and found that the greater the initial nitrogen content of the feedstock, the greater the ammonia loss by volatilization during composting. The researchers did not add or evaluate the effects of phosphorus because they said phosphorus is not usually added during composting operations (Komilis and Ham, 2000).

Phosphorus chemistry is complex, and it is difficult to predict with accuracy the correspondence between soil phosphorous concentrations and solubility, and plant phosphorous status for plants (Bohn et al., 1985). Rock phosphate, bone meal, and compost from phosphate-rich sources can all provide adequate phosphorous in potting soils. There appear to be considerably more alternatives to compost with superphosphates for field use outside of use in potting media. At high pH, the mined minerals variscite and strengite are soluble and should make good fertilizers if finely ground (Bohn et al., 1985). These would be phosphorus sources that could be substituted for triple superphosphate.

In addition to all the alternatives listed above, mulches and green manures (Lampkin, 1990) are used for both phosphate cycling and nitrogen conservation. Rotating legumes can enhance rock phosphate mobilization in alkaline soils where P would otherwise be relatively unavailable (Aguilar and van Diest, 1981). Composting low-grade rock phosphate [allowed in the Final Rule at 205.203(d)(2)] can enhance P availability to be comparable to applications of single superphosphate (Singh and Amberger, 1995). VAM makes relatively insoluble phosphorous more available (Virant-Klun and Gogala, 1995).

7. *Its compatibility with a system of sustainable agriculture.*

Acidified phosphorous fertilizer in general, and triple superphosphate in particular, is one of the specific items used in the discussion of the sustainability of organic farming systems. One of the defining characteristics long-used to identify organic farms is the production of crops without acidified phosphorous fertilizer such as superphosphate or triple superphosphate (Lockeretz, Shearer, and Kohl, 1981). Approaches that use relatively insoluble sources of P and enhanced activity of P-solubilizing bacteria may provide a more biorational and sustainable approach to P fertilization than the use of acidulated P-fertilizers such as superphosphates (Goldstein, 1986).

Farmers who engage in practices that are largely sustainable and long-time proponents of organic farming have questioned the sustainability of prohibiting chemically refined phosphorous fertilizer (for example, Logsdon, 1993). Many of the practices that are cited as reasons why triple superphosphate is not sustainable can be applied to the alternatives as well (Parnes, 1990). None of the sources who see triple superphosphate as sustainable state so without qualification, including in the petition as a soil amendment. Research and crop management guides for sustainable soil management generally recognize that most soluble sources of phosphate are usually applied in excess and most does not go to the plant. The USDA (1980) estimated that most farmers could eliminate phosphate applications and not suffer yield reductions, at least in the short run. Even when not eliminated, phosphate applications can be better used through reduced and split applications, increased testing, and soil conservation practices (Cramer, 1986; National Academy of Sciences, 1988).

Because it is produced by a synthetic manufacturing process from non-renewable resources and has relatively high solubility compared with the alternatives, triple superphosphate is generally not considered compatible with a system of sustainable agriculture.

TAP Reviewer Discussion²

Reviewer 1

[Midwest--provides technical services to growers, extensive experience in organic and sustainable agriculture]

Reviewer 1 submitted substantial comments and corrections to the text of the review (and these are incorporated in), voted that the material is synthetic and should not be added to the National List, and did not have any additional points for discussion.

Reviewer 2

[West--researcher and consultant for organic growers, certification experience]

There are adequate organically acceptable materials and practices to the use of this material for composting. The effect on pH of the compost materials from the addition of the triple super phosphate appears to be nominal, from the applicant's own information. Thus its need to be used for pH adjustment seems inconsistent with the applicants own experience. Additionally, there are organically acceptable alternatives that will significantly address the ammonia volatilization issues. The material is inconsistent with the long held practice of stimulating soil biological activity to provide fertility for crops. The material is prohibited by virtually all national and international organic certifiers. Increasing the solubility of phosphorus can lead to the reduction of mycorrhizae, which are essential to healthy organic plants.

Reviewer 3

[East--doctorate in plant pathology, M.S. soil science, expertise in compost management]

[H]igh nitrogen compost feedstocks are blended with high carbon feedstocks to optimize the composting process and reduce ammonia loss. Ammonia volatilization during manure composting is recognized as a problem. Researchers have shown that ammonia volatilization can be reduced during manure composting by adding MSW to increase the carbon content of the feedstock (Sikora, 1999). If the petitioners wish to reduce ammonia volatilization, increasing the carbon content of their compost feedstock would be an effective method.

The petitioners also indicate that TSP is beneficial to their composting process. This reviewer has not found articles evaluating the impact or interaction of TSP in the composting process. There is a body of literature that evaluates leaching of phosphorus under various conditions. Siddique et al. (2000) found that soils fertilized with monocalcium phosphate leached P more than did soils amended with anaerobically treated sewage sludge. Although these sludges were treated with a biological anaerobic process, it is not clear from the article if chemical flocculants were added to the sludge during the dewatering process. Chemical flocculants can greatly affect nutrient retention properties of sludge. The authors found that as much as 80% of the P in the sludge was in an inorganic, unavailable form. Sharpley and Sisak (1997) found that P availability was greater in soils fertilized with KH_2PO_4 than with uncomposted poultry litter. Because of the complexity of phosphorus chemistry and the variables involved in composting versus raw manure or sludge application this reviewer can not evaluate the changes to TSP and its availability during and after the composting process without further information.

In general the applicant has options available to them to provide a phosphorus source, reduce ammonia loss, and reduce pH other than using TSP. For this and reasons discussed above this reviewer feels TSP should not be added to the national list.

This reviewer wishes to raise an issue that is beyond the scope of this current review but should be evaluated by the organic community at some point. This is the need for a comparison and consideration of the efficiency of rock phosphate versus triple super phosphate (TSP) in light of the extensive environmental damage caused by the mining of rock phosphate. The evaluation should include which product, rock phosphate or TSP causes the greatest overall environmental damage in terms of volume of land that is mined to meet agricultural production, processing, soil and water quality impacts. This is a complicated issue because it involves mining, processing and use impacts. Again it is clearly beyond the scope of this review but deserves consideration at some point.

² OMRI's information is enclosed in square brackets in italics. Where a reviewer corrected a technical point (e.g., the word should be "intravenous" rather than "subcutaneous"), these corrections were made in this document and are not listed here in the Reviewer Comments. The rest of the TAP Reviewer's comments are edited for any identifying comments, redundant statements, and typographical errors. Additions to the TAP review text were incorporated into the review. Text removed is identified by ellipses [...]. Statements expressed by reviewers are their own and do not reflect the opinions of any other individual or organizations.

References

Those marked with an asterisk* are included with this TAP review.

Aguilar, S. and A. van Diest. 1981. Rock-phosphate mobilization induced by the alkaline uptake patten of legumes utilizing symbiotically fixed nitrogen. *Plant and Soil* 61: 27-42.

*Amijee, F., P.B. Tinker, and D.P. Stribley. 1989. The development of endomycorrhizal root systems. VII. A detailed study of effects of soil phosphorous on colonization. *New Phytologist* 111: 435-446.

*Appropriate Technology Transfer for Rural Areas (ATTRA) (1999). Manure management using phosphates. Fayetteville, AR: ATTRA.

Association of American Plant Food Control Officials (AAPFCO). 2000. *Official Publication*. Raleigh, NC: AAPFCO.

*Azcon, R., J.M. Barea and D.S. Hayman. 1976. Utilization of rock phosphate in alkaline soils by plants inoculated with mycorrhizal fungi and phosphate-solubilizing bacteria. *Soil Biology and Biochemistry* 8: 135-138.

*Baker, W.G. 1925. Residual effects of acid phosphate and rock phosphate. *Agronomy Journal* 25: 172-186.

*Bangar, C., K.S. Yadav, and M.M. Mishra. 1985. Transformation of rock phosphate during composting and the effect of humic acid. *Plant and Soil* 85: 259-266.

Bierman, L.W. and G.L. Long. 1978. Direct Granulation Process for Triple Superphosphate. US Patent No. 4,101,637.

*Bohn, H.L., B.L. McNeal, and G.A. O'Connor. 1979. *Soil Chemistry* (1st ed.). New York: Wiley-Interscience.

Bohn, H., B. McNeal, and G. O'Connor. 1985. *Soil Chemistry*, (2nd ed.) Wiley-Interscience Publication.

Brady, N.C. 1974. *The Nature and Properties of Soil*. (8th Ed.) New York: MacMillan.

Brinton, W.F. and D. W. Tresemer. 1988. Organic growing media: Research into the use of compost for potting mix nutrition. Paper presented at the IFOAM Scientific Conference, Santa Cruz, CA, 1988.

*Brown, K.H., Bouwkamp, J.C. and F.R. Gouin. 1998. The influence of C:P ratio on the biological degradation of municipal solid waste. *Compost Science and Utilization* 6: 53-58.

Budavari, S. 1996. *Merck Index*. Whitehouse Station, NJ: Merck & Co.

Bunt, A.C. 1976. *Modern Potting Composts*. University Park: The Pennsylvania State University Press.

Bunus, F. T. 1994. Phosphoric acid by wet process: Radioactive components in phosphoric acid and their removal, in C.A. Hodge and N.N. Popovici (eds.), *Pollution Control in Fertilizer Production* 237-252. New York: Marcel Dekker.

*Canadian Organic Growers. 1992. Manure management and composting. Chapter 1.4 in *COG Organic Field Crop Handbook: Cognition*. http://cap.mcgill.ca/MagRack/COG/COGHandbook/COGHandbook_1_4.htm

Carter, L.S. and C.E. Millar. 1934. The effect of superphosphate, hydrated lime, and straw on the loss of nitrogen from manure during storage. *Michigan Quarterly Bulletin* 16: 136-146.

Center for Environmental Analysis. 1999. *Estimating Risk from Contaminants Contained in Agricultural Fertilizers*. Research Triangle Park, NC: Research Triangle Institute.

Charter, R.A., M.A. Tabatabai, and J.W. Schafer. 1993. Metal contents of fertilizers marketed in Iowa. *Communications in Soil Science and Plant Analysis* 24: 961-972.

Clapperton, M.J., H.H. Janzen, and A.M. Johnston. 1997. Suppression of VAM fungi and micronutrient uptake by low-level P fertilization in long-term wheat rotations. *American Journal of Alternative Agriculture* 12: 59-63.

Collings, G.H. 1950. *Commercial Fertilizers: Their Sources and Use*. Philadelphia: Blakiston.

- Collison, R.C. and H.J. Conn. 1922. A study of certain preservatives and their effect on the fertilizing value of manure. *New York State Agricultural Experiment Station Bulletin* 494: 28-74.
- Cooke, G.W. and R.J.B. Williams. 1973. Significance of man-made sources of phosphorus: Fertilizers and farming. *Water Research* 7: 19-33.
- Cramer, C. (ed.) 1986. *The Farmer's Fertilizer Handbook*. Emmaus, PA: Regenerative Agriculture Association.
- Follett, R.H., L.S. Murphy, and R.L. Donahue. *Fertilizers and Soil Amendments*. Englewood Cliffs, NJ: Prentice-Hall.
- Foster-Wheeler Environmental Corporation. 1998. *Development of Risk-Based Concentrations for Arsenic, Cadmium, and Lead in Inorganic Commercial Fertilizers*. Sacramento: California Department of Food and Agriculture and Heavy Metal Task Force.
- Goldstein, A.H. 1986. Bacterial solubilization of mineral phosphates: Historical perspective and future prospects. *American Journal of Alternative Agriculture* 1: 51-57.
- *Górecki, H.J. 1994. Granular triple superphosphate and single superphosphate, in C.A. Hodge and N.N. Popovici (eds.), *Pollution Control in Fertilizer Production* 269-298. New York: Marcel Dekker.
- Heck, A.F. 1931. Conservation and availability of nitrogen in farm manure. *Soil Science* 31: 335-359.
- *Hicks, P.M. and T.E. Loynachan. 1987. Phosphorus fertilization reduces vesicular-arbuscular mycorrhizal infection and changes node occupancy of field-grown soybean. *Agronomy Journal* 79: 841-844.
- *Hoffmeister, G. 1993. Fertilizers. *Kirk-Othmer Encyclopedia of Chemical Technology* (4th Ed.) 10: 433-514.
- International Federation of Organic Agriculture Movements (IFOAM). 2000. *Basic Standards*. Tholey-Theley, Germany: IFOAM.
- *IMC Fertilizer. 1988. Material Safety Data Sheet for triple superphosphate. Mundelein, IL: IMC Fertilizer.
- *Jasinski, S.M. 1999. Phosphate rock, in the US Geological Survey *Minerals Yearbook*. http://minerals.usgs.gov/minerals/pubs/commodity/phosphate_rock/540499.pdf
- Karrabaker, P.E., H.F. Miller, C.E. Bortner, and J.R. Todd. 1941. Greenhouse tests of the availability of phosphorus in certain phosphate fertilizers. *Kentucky Agricultural Experiment Station Bulletin* 413: 57-86.
- *Komilis, D.P. and R.K. Ham. 2000. A Laboratory method to investigate gaseous emissions and solids decomposition during composting of municipal solid wastes. *Compost Science and Utilization* 8: 254-265.
- Kpombekou, K., S.H. Chien, J. Henao, and W.A. Hill. 1991. Greenhouse evaluation of phosphate fertilizers produced from Togo phosphate rock. *Communications in Soil Science and Plant Analysis* 22: 63-73.
- Lampkin, N. 1990. *Organic Farming*. Ipswich, UK: Farming Press.
- Lengnick, L.L. and L.D. King. 1986. Comparison of the phosphorus status of soils managed organically and conventionally. *American Journal of Alternative Agriculture* 1: 108-114.
- *Lindsay, J.B. 1912. Chemical methods for the preservation of manure. *Massachusetts Agricultural Experiment Station Annual Report* 24: 31-34.
- Lockeretz, W., G. Shearer, and D.H. Kohl. 1981. Organic farming in the Corn Belt. *Science* 211: 540-547.
- Logsdon, G. 1993. *The Contrary Farmer*. Post Mills, VT: Chelsea Green Publishers.
- Ludwick, A.E., K.B. Campbell, R.D. Johnson, L.J. McClain, R.M. Millaway, S.L. Purcell, I.L. Phillips, Jr., D.W. Rush, and J.A. Waters. *Western Fertilizer Handbook: Horticulture Edition*. Danville, IL: Interstate Publishers.

- *MacKay, A.D., J.K. Syers, and P.E.H. Gregg. 1984. A glasshouse comparison of six phosphate fertilizers. *New Zealand Journal of Experimental Agriculture* 12: 131-140.
- Maine Organic Farmers and Gardeners Association (MOFGA). 2001. *Organic Certification Standards*. Unity: MOFGA.
- Maynard, D.N. and G.J. Hochmuth. 1997. *Knott's Handbook for Vegetable Growers* (4th Ed.). New York: John Wiley & Sons.
- Meister, R.T. (ed.) 2001. *Farm Chemicals Handbook*. Willoughby, OH: Meister Publishing.
- Midgley, A.R. and D.E. Dunklee. 1945. The availability to plants of phosphates applied with cattle manure. *University of Vermont Agricultural Experiment Station Bulletin* 525.
- Midgley, A.R. and W.O. Mueller. 1940. The effect of lime on the nitrogen content of cow manure. *University of Vermont Agricultural Experiment Station Bulletin* 456.
- Midgley, A.R. and V.L. Weiser. 1937. Effect of superphosphates in conserving nitrogen in cow manure. *University of Vermont Agricultural Experiment Station Bulletin* 419.
- Mortvedt, J.J. 1987. Cadmium levels in soils and plants from some long-term soil fertilizer experiments in the United States of America. *Journal of Environmental Quality* 16:137-142.
- National Research Council. 1989. *Alternative Agriculture*. Washington, DC: National Academy Press.
- Nelson, P.V. 1985. *Greenhouse Operation and Management*. Reston, VA: Reston Publishing.
- *Nelson, P.V. 1990. Developing root zone management strategies to minimize water and fertilizer waste: The United States perspective with emphasis on surface applied non-recirculated systems. *Acta Horticulture* 272: 175-184.
- New Hampshire Agriculture Administrative Rule. Part 906 Certification of Organically Grown Foods.
<http://www.state.nh.us/agric/agr906.html>
- Ober, J. 1999. Sulfur. *US Geological Survey Minerals Yearbook —1999*. Washington, DC: US Government Printing Office.
<http://minerals.usgs.gov/minerals/pubs/commodity/sulfur/640499.pdf>
- Oh, Young-Mi, D.L. Hesterberg, and P.V. Nelson. 1999. Comparison of phosphate adsorption on clay minerals for soilless root media. *Communications in Soil Science and Plant Analysis* 30: 747-756.
- *Parnes, R. 1990. *Fertile Soil: A Grower's Guide to Organic and Inorganic Fertilizers*. Davis: AgAccess.
- *Petersen, R.L. and M.B. Freilich. 1992. Calcium compounds (survey). *Kirk-Othmer Encyclopedia of Chemical Technology* 4: 787-796.
- Phillips, A.B. and J.R. Webb. 1971. Production, marketing, and use of phosphorus fertilizers, in R.A. Olson, T.J. Army, J.J. Hanway, and V.J. Kilmer, *Fertilizer Technology and Use* (2nd edition): 271-301. Madison, WI: Soil Science Society of America.
- Rader, L.F., L.M. White, and C.W. Whittaker. 1943. The salt index—A measure of the effect of fertilizers on concentration of the soil solution. *Soil Science* 55: 201-208.
- *Ramsey, T. 1990. The compost materials in Living Acres Kompost-1® and the permissibility status of Kompost-1® and products containing Kompost-1®. Letter to Concerned Organic Certification Committees, October 15.
- *_____. 2000. Petition for amendment to the National List: "Active Synthetic Substances Allowed for Use in Organic Crop Production." Petition to the National Organic Program and the National Organic Standards Board.
- Rynk, R., M. van de Kamp, G. B. Willson, M.E. Singley, T.L. Richard, J.J. Kolega, F.R. Gouin, L.Laliberty Jr., D. Kay, D.W. Murphy, H.A.J. Hoitink, and W.F. Brinton. 1992. *On-farm Composting Handbook*. Ithaca, NY: Northeast Regional Agricultural Engineering Service.

- *Sharpley, A.N. and I. Sisak. 1997. Differential availability of manure and inorganic sources of phosphorus in soil. *Soil Science Society of America Journal* 61:1503-1508.
- Sheppard, M., L. Phillips, and A. Bhogal. 2000. Manure management on organic farms: To compost or not to compost. *Proceedings 13th International IFOAM Scientific Conference*.
- *Siddique, M.T., Robinson, J.S. and B.J. Alloway. 2000. Phosphorus reactions and leaching potential in soils amended with sewage sludge. *Journal of Environmental Quality* 29: 1931-1938.
- *Sikora, L.J. 1999. MSW compost reduces nitrogen volatilization during dairy manure composting. *Compost Science and Utilization* 7: 34-41.
- *Singh, C.P. and A. Amberger. 1995. The effect of rock phosphate-enriched compost on the yield and phosphorous nutrition of rye grass. *American Journal of Alternative Agriculture* 10: 82-87.
- *Thomson, B.D., A.D. Robson, and L.K. Abbott. 1992. The effect of long-term application of phosphorous fertilizer on populations of vesicular-arbuscular mycorrhizal fungi in pastures. *Australian Journal of Agricultural Research* 43: 1131-1142.
- Tisdale, S.L. and W.L. Nelson. 1966. *Soil Fertility and Fertilizers* (2nd Ed). New York: MacMillan.
- Tisdale, S.L., Nelson, W.L., and J.D. Beaton. 1985. *Soil Fertility and Fertilizers* (4th Ed.). New York: MacMillan.
- Tottingham, W.E. and C. Hoffman. 1913. Nature of the changes in the solubility and availability of phosphorous in fermenting mixtures. *University of Wisconsin Agricultural Experiment Station Bulletin* 29.
- Uncles, R. 2001. New Hampshire Department of Agriculture. Personal communication, April 4.
- US Department of Agriculture (USDA). 1980. *Report and Recommendation on Organic Farming*. Washington, DC: US Government Printing Office.
- US Environmental Protection Agency, Office of Pollution Prevention and Toxics (US EPA). 1999a. *Background Report On Fertilizer Use, Contaminants And Regulations*. <http://www.epa.gov/oppt/fertilizer.pdf>.
- US Environmental Protection Agency, Office of Pollution Prevention and Toxics (US EPA). 1999b. *Background Report Ap-42 Section 6.10 Phosphate Fertilizers*. <http://www.epa.gov/ttnchie1/ap42/ch08/bgdocs/b08s05.pdf>
- US Geological Survey. 2001. Phosphate rock. *Mineral Commodity Summaries*. http://minerals.usgs.gov/minerals/pubs/commodity/phosphate_rock/540301.pdf
- Van Horn, M. 1995. *Compost Production and Utilization: A Grower's Guide*. Oakland: University of California Division of Agriculture and Natural Resources Publication 21514.
- *Virant-Klun, I. and N. Gogala. 1995. Impact of VAM on phosphorous nutrition of maize with low soluble phosphate fertilization. *Journal of Plant Nutrition* 18: 1815-1823.
- *Vivenkanandan, M. and P.E. Fixen. 1991. Cropping systems effects on mycorrhizal colonization, early growth, and phosphorous uptake of corn. *Soil Science Society of America Journal* 55: 136-140.
- Wakefield, Z.T. 1980. *Distribution of Cadmium and Selected Heavy Metals in Phosphate Fertilizer Processing* (Bulletin Y-159). National Fertilizer Development Center, TVA.
- Warren, R.G. and A.E. Johnston. 1961. Barnfield. *Report for the Rothamstead Experiment Station for 1960*: 227-247.
- *Yeager, T.H. and J.E. Barrett. 1984. Phosphorous leaching from ³²P-superphosphate-amended soilless container media. *HortScience* 19: 216-217.
- *Yeager, T.H. and J.E. Barrett. 1985. Phosphorous and sulfur leaching from an incubated superphosphate-amended soilless container media. *HortScience* 20: 671-672.

*Yeager, T.H. and J.E. Barrett. 1986. Influence of an anion exchange resin on phosphorous and sulfur leaching from a soilless container media. *HortScience* 21: 152.

*Yushok, W. and F.A. Bear. 1943. Poultry manure: Its preservation, deodorization, and disinfection. *New Jersey Agricultural Experiment Station* 707.

This TAP Review was completed pursuant to United States Department of Agriculture Purchase Order 40-6395-0.