National Organic Standards Board
Livestock Subcommittee
Petitioned Material Proposal
Aluminum Sulfate
June 21, 2016

Summary of Petition:
In August 2013 the NOP received a petition to add Aluminum Sulfate to the National List of synthetic substances allowed for use in organic livestock production 7 CFR 205.603 as a poultry litter treatment.

Summary of Review:
Manufacture and Uses of the Substance:
The intended and current use of aluminum sulfate is to be used as a poultry and livestock bedding amendment. Aluminum sulfate has been used in poultry, turkeys and livestock production for decades to safely and effectively protect animals and caretakers from volatilized ammonia that is generated from poultry and livestock manure, which accumulates in poultry and livestock bedding. For the sake of clarification, the term litter will be used synonymously with bedding and mixtures of used bedding and manure. Volatilized ammonia that occurs from the natural decomposition process in litter is the result of bacterial enzyme hydrolysis of uric acid to urea which is further hydrolyzed to ammonia (NH3). Ammonia has been shown to be detrimental to animal health, livability, well-being and overall live performance. Aluminum sulfate reacts with ammonia by donating acid ions, converting ammonia (NH3) to ammonium (NH4+), a highly reactive ion that bonds with nitrates, phosphates and sulfates forming stable non-volatile ammonium salts that are retained in the litter, which improve the litter's nutrient value as a natural fertilizer. In addition to litter treatment in the poultry house, aluminum sulfate is being petitioned for use in organic crop production as a poultry litter additive. Litter treated with aluminum sulfate differs from non-treated litter, as it contains more total nitrogen and less soluble phosphorous, which increases the nitrogen fertilizer value and reduces phosphorous pollution of surface waters (Moore and Watkins 2012).

By retaining nitrogen in the litter through the conversion of NH3 to NH4+, and by binding soluble phosphorus, the fertilizer nutrient value of alum treated litter is improved. When land applied, litter that has been treated with alum contains bound soluble phosphorus that is utilized by plants on an as need basis. Plants have the ability to secrete acid from their roots to break the aluminum phosphate bonds re-solubilize phosphorus, making the essential nutrient available to plants. Aluminum sulfate in water treatment is classified as a flocculent and its function is to precipitate silica, minerals and organic material out of suspension. It is incorporated as one of the initial steps in municipal water purification. Aluminum sulfate based products have also been used for decades in municipal water treatment and lake restorations in the US and Canada. Over 50% of the municipal water in the US is treated with Chemtrade aluminum sulfate, the sponsor for this petition and aluminum sulfate is the most widely used water clarification chemical in the world.

Dry aluminum sulfate is applied using drop spreaders, and centrifugal (slinger) spreaders, varying in size and complexity depending on application demand. Liquid aluminum sulfate is applied using a vehicle designed with a storage tanks, a pump and a PVC spray wand equipped with stainless steel nozzles. Typical dry product application rates range from 50 to 200 lbs/1000 ft2. Typical liquid product application rates range from 20 to 55 gal/1000 ft2. Dry aluminum sulfate is either applied by the poultry farmer or by custom applicators. Liquid aluminum sulfate and acidified aluminum sulfate products are applied by custom applicators.

The manufacturing process for all the forms of aluminum sulfate included in the petition involves reacting liquid sulfuric acid with either bauxite ore containing aluminum hydroxide (Al(OH)3) and hydrated aluminum (Al2O3·3H2O), or synthetic hydrated aluminum previously refined from bauxite. Bauxite ore is the main source of aluminum for the world and contains various aluminum minerals and two iron minerals (Amethyst Galleries 2014). The process creates hydrated aluminum sulfate per the following reactions:

From bauxite: $3 H_2SO_4 + 2 Al(OH)_3 + 12 H_2O \rightarrow Al_2(SO_4)_3 \bullet 18 H_2O$ 52
From hydrated aluminum: $3 H_2SO_4 + Al_2O_3 \cdot 3H_2O + 12 H_2O \rightarrow Al_2(SO_4)_3 \cdot 18 H_2O$ 53

The acidified formulation also contains synthetically produced sulfuric acid.

During the Spring 2016 in-person public comment session at the National Organic Standards Board meeting in Washington, DC, the board received one public comment that stated that there are OMRI listed poultry litter amendments currently in use. The Board was provided information from a manufacturer of a poultry litter amendment product, which is currently OMRI listed, that expressed concerns they had with the TR. The commenter felt that the board should not approve synthetic poultry litter amendments when there are already effective OMRI listed products being used in the marketplace.

Category 1: Classification

1. **Substance is used for:** Livestock

2. **For LIVESTOCK use:**
   a. Is the substance agricultural or non-agricultural? This substance is non-agricultural

   b. If the substance is non-agricultural, is the substance: non-synthetic or synthetic. This substance is synthetic

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      The acidified formulation also contains synthetically produced sulfuric acid.

3. **For LIVESTOCK**: This product would be listed at 205.603 Livestock Production-Synthetic. The substance contains sulfur. The substance is not an inert ingredient. Aluminum sulfate is **not** classified by the EPA as an inert of toxicological concern (it is on EPA List 4 (2004)). The substance is, however, approved as an adjuvant, used pre-harvest, and is exempted from the requirement of a tolerance (40 CFR 180.920).

Category 2: Adverse Impacts

1. **What is the potential for the substance to have detrimental chemical interactions with other materials used in organic farming systems? [§6518(m)(1)]**

   TR LINES 435-478

   Aluminum sulfate is being petitioned as an amendment to poultry litter for consideration in organic livestock application. Aluminum sulfate undergoes various chemical interactions with the poultry litter, altering several key chemical characteristics of the litter:

   1. The pH of the litter is reduced; however it is unlikely to fall below pH 7.0 in litter collected after the final grow out flock. Initially the treated litter pH does fall to about 5.7 and that pH is maintained for about 3-4 weeks (Moore et al. 2000) (Table 2).

   2. Aluminum sulfate reacts with water and naturally-occurring NH3 in the litter to form NH4+, thus stabilizing nitrogen and reducing NH3 gas volatilization to the atmosphere. In the soil environment, NH4+ is transient and is either rapidly taken up by plants, microbially transformed to NO32- which can be taken up by plants or lost to leaching, or anaerobically transformed by microorganisms to N2 and N2O which are lost to the atmosphere (Halvin et al. 2005). Although nitrogen is more persistent in the litter, there is no effect on cumulative soil nitrogen accumulation compared to non-treated litter, as aluminum sulfate does not alter the organic fraction of the total nitrogen.

   Poultry litter is a significant source of NH3 in the atmosphere, which causes formation of aerosol particles. It is also a source of nitric acid deposition to land or water bodies where it causes land and water acidification and nitrate pollution (NOAA 2000). Aluminum sulfate decreases atmospheric pollution of NH3 by reducing litter pH, which converts NH3 to water-soluble NH4+ (Shah et al. 2006). Incubation studies estimate approximately 14 g N / kg litter is lost from non-treated litter as NH3, while ammonia loss from litter treated with aluminum sulfate ranges between 0.7 to 4.07 g N / kg litter between the high and low application rates (Moore et al. 2000. Assuming 40,000 lbs. of litter for a 16,000 square foot poultry house containing 20,000 broilers (Moore and Watkins 2012), this represents a reduction of about 400 lbs. of NH3-N lost to the atmosphere over a 42-day period with low rates of aluminum sulfate, and about 560 lbs. of NH3-N at high rates of aluminum sulfate.

   3. Litter treated with aluminum sulfate contains less soluble phosphate (PO43-) than non-treated litter, as Al3+ reacts with PO43- to form insoluble AlPO4 (Table 2). Although the total phosphorous concentration in the litter does not change greatly, phosphorous becomes less plant-available, and likelihood of phosphorous transport to surface water is reduced. Aquatic ecosystems tend to be phosphorous-limited, and phosphorous eutrophication of natural water

bodies is reduced when land-applied litter is treated with aluminum sulfate. The insoluble aluminum phosphate is not available to plants as nutrients and instead stays in the soil as a mineral (Moore and Edwards 2005).

4. Litter treated with aluminum sulfate contains both higher total aluminum and higher soluble aluminum than non-treated litter (Table 2); however, runoff from fields where aluminum sulfate-treated litter is applied does not contain significantly higher levels of aluminum than fields where non-treated litter is applied (Moore et al. 1998).

5. Litter treated with aluminum sulfate contains higher total sulfur and higher soluble sulfur than non-treated litter (Table 2).

6. Concentration of soluble arsenic is reduced by aluminum sulfate treatment due to arsenic co-precipitation by aluminum (Violante et al. 2006) (Table 2).

2. **What is 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? [§6518(m)(2)]**

TR LINES 356-387

Toxicity: Aluminum sulfate is considered a dry acid, and is an irritant to the skin and eyes (UN-LIO 2012). However, acidity created by the substance is neutralized by the litter, and litter applied to land generally has a near-neutral pH (Sims and Luka-McCafferty 2002).

Mode of action: Aluminum sulfate reacts with water to create acid, which reduces ammonia losses from litter in confined poultry operations. Furthermore, aluminum causes precipitation of phosphates, reducing phosphorus solubility in the land-applied litter (Moore and Watkins 2012).

Breakdown products: Breakdown products of aluminum sulfate include Al3+, Al(OH)2+, Al(OH)2+, Al(OH)3, SO42-, HSO4-, and H2SO4, and H3O+ (McBride 1996). Aluminum phosphate (Al(PO4)) precipitate is also formed via reaction of Al3+ with phosphates in the litter (Warren et al. 2008).

Toxicity of breakdown products: Free Al3+ is a toxic species that increases in concentration as pH decreases, and typically reaches phytotoxic levels when pH falls below 5.0 (Havlin et al. 2005). Poultry litter without aluminum sulfate typically ranges in pH from 8.0 to 8.9 (Sims and Luka-McCafferty 2002). Shortly after aluminum sulfate application, pH of the litter decreases to about 5.7, but becomes neutralized (near pH 7.0) after 3-4 weeks due to reaction with NH3 in the poultry guano (Moore et al. 2000). Thus, although adding aluminum sulfate increases total concentration of aluminum, persistence of the toxic Al3+ species is not enhanced. In contrast, application of litter near pH 7.0 to acidic soils decreases solubility of toxic Al3+ (Moore and Edwards 2005).

Persistence of the breakdown products: Aluminum hydroxide and phosphates from aluminum sulfate addition to poultry litter are persistent in the soil after land application due to low solubility (Warren et al. 2008). Sulfates, however, are more soluble, serve as a source of sulfur for crop plants, or are lost to leaching (Havlin et al. 2005).

Contaminants: The primary contaminants present in the Al_2O_3 precursor to aluminum sulfate include SiO_2, Fe_2O_3, and Na_2O, and could carry though into the final aluminum sulfate product, however do not pose toxicological concerns (Carter and Norton 2007)

3. Describe the probability of environmental contamination during manufacture, use, misuse or disposal of such substance? [§6518(m)(3)]

TR LINES 392-429

Aluminum sulfate is a dry acid, and can create zones of high acidity if accidentally spilled. Acid damage severity from a concentrated spill is dependent on the quantity spilled, and also on the moisture available for reacting. If the spilled material does not come into contact with moisture, the majority of the material could be cleaned up before significant acidification occurs. . But, surfaces of most soils are typically fissured and loose, and sometimes moist, making complete soil cleanup unlikely. Aluminum sulfate is designated as a hazardous substance under the CERCLA (superfund), and discharges exceeding 5,000 lbs (2,270 kg) require notification to the U.S. Environmental Protection Agency (TABLE 302.4 40 CFR).

Localized environmental acidification has a profound impact on chemical equilibrium regulating biological systems. In the soil, acidic conditions cause enhanced solubility of the Al^{3+} species, which is toxic to plant roots. Furthermore, both H^+ and Al^{3+} are more strongly adsorbed to soil cation exchange sites than calcium, magnesium, and potassium and cause potential soil depletion of these nutrients via leaching. Soil remediation of large aluminum sulfate spills can be accomplished with a liming agent to neutralize the acidity and reduce solubility of Al^{3+} (NIH 2014).

Aluminum sulfate is sometimes deliberately added to water bodies impaired by phosphorus eutrophication, but accidental discharge of large quantities could cause excessive water acidification and subsequent solubilization of Al^{3+} which is toxic to aquatic organisms (UN-ILO 2012).

Personal protective equipment should be used when applying aluminum sulfate in the poultry house, but no specific precautions are needed for handling spent litter treated with aluminum sulfate due to the high level of dilution in the litter. In the poultry house, any aluminum sulfate spills should be incorporated into the litter to prevent ingestion by the birds (Walker and Burns 2000). Applications of liquid ammonium sulfate are typically made by certified applicators due to transport restrictions (Moore and Watkins 2012).

Aluminum sulfate reduces environmental contamination of phosphorus in natural water bodies from surface litter applications, compared to non-treated litter. Moore and Edwards (2005) measured 340% greater cumulative phosphorus load in runoff water from non-treated litter than from treated litter in a paired watershed study.

The process of extracting bauxite ore has a deleterious impact on the environment through habitat degradation and fragmentation by roads, and through carbon emissions (Cooke 1999). After extraction, regulations in some countries require replacement of topsoil and other remediation measures; however quality of land after remediation is unlikely to be equivalent to before-extraction parameters (Cooke 1999). Most of the bauxite extraction worldwide is for the production of aluminum oxide, and less than 5% of bauxite imported into the U.S. is used for other purposes including aluminum sulfate production (USGS 2014)

4. Discuss the effect of the substance on human health. [§6517 (c)(1)(A)(i); §6517 (c)(2)(A)(i); §6518(m)(4)].

TR LINES 544-563

Aluminum sulfate reacts with water to form sulfuric acid, which is an irritant. Aluminum sulfate is corrosive to the eyes; skin contact causes a rash and burning feeling, and inhalation causes throat and lung irritation (New Jersey Department of Health 2009). The magnitude of the toxic response to aluminum sulfate is completely dose-dependent, and the substance is permitted as a food additive in small quantities. Minor ingestion of dilute solutions causes stomach upset, while substantial ingestion can rarely cause hemorrhagic gastritis, circulatory collapse and multi-organ failure (United Kingdom National Poisons Information Service 1996).

Aluminum is a subject of medical contention with suspected links to Alzheimer's disease. Implications of a link between Alzheimer's disease and aluminum have been made for approximately 40 years. The current large body of research has not concluded specific roles of aluminum in contributing to Alzheimer's disease, but also has not dismissed aluminum as a non-contributor to the disease (Agency for Toxic Substances and Disease Registry 2008; Exeley 2001). Under FDA regulations, aluminum sulfate is generally recognized as safe (GRAS) as a food additive when used in accordance with good manufacturing or feeding practice (CFR 182.1125(b)).

Although aluminum sulfate has chronic toxicity for human exposure, use of the substance as petitioned should not have negative effects on human health. Use of the substance as petitioned decreases ammonia concentration in the atmosphere of poultry houses, which has a positive impact on both health of the birds and health of workers (Moore et al., 2000).

5. Discuss any effects the substance may have 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. [§6518(m)(5)]

TR LINES 485-522

Aluminum sulfate is not applied while birds are in the poultry house. The substance is not applied before the first flock grow-out; however, it is systematically applied thereafter before every flock is exposed to the litter. Any spills or concentrations of the product should be dispersed into the litter to avoid consumption by young chicks (Walker and Burns 2000). As stated in the petition, aluminum sulfate is not applied to feed. In the event of accidental ingestion, aluminum sulfate is corrosive and irrigating to the digestive system and kidneys of birds (Dumonceaux and Harrison 2013). In one study, Japanese quail fed aluminum sulfate as >0.10% of their diet reduced body weight accumulation, eggshell strength, plasma inorganic phosphorous, feed consumption, and egg production (Hussein et al. 1988). Physiological effects of aluminum sulfate intake by broiler chickens occurs at higher intake levels than quail, with decreases in weight gain when consumed at >0.93% of the diet. Higher concentrations of aluminum sulfate in the diet cause more severe depressions in weight gain, decreased bone strength, and serum phosphorous. At application rates of 100 g / kg litter, birds would need to ingest 10% of total dietary intake as litter to exceed 0.93% aluminum sulfate in the diet, and the aluminum would need to be in the original non-reacted aluminum sulfate crystalline form which does not persist in the presence of moisture. Typical observed litter ingestion rates are below this threshold, ranging from 2% to 5% of daily dietary intake. Aluminum sulfate is toxic to poultry if directly ingested in large quantities, but not at levels expected from litter consumption (Huff et al. 1996). When aluminum sulfate is used, mortality decreases and poultry weight gain increases, indicating the birds are likely not suffering toxic effects from incidental aluminum sulfate ingestion from the litter (Walker and Burns 2000).

Deleterious effects of aluminum sulfate on the head, skin, feathers, or feet of poultry were not revealed in the literature review, but the material is an irritant (UN-LIO 2012). If aluminum sulfate remains in its original non-reacted dry form, there is potential for foot irritation. Producers can mitigate the potential of bird exposure by rototilling aluminum sulfate into the litter after application, and before birds are placed back in the poultry house. Liquid formulations are less likely to expose birds to concentrations of the chemical due to greater dispersal in the litter compared to dry formulations (Moore and Watkins 2012). Aluminum sulfate tends to dry out the litter, and in turkeys the use of aluminum sulfate decreased the incidence of foot pad dermatitis, which is associated with wet litter (Wu and Hocking 2011).

In addition to the phosphorous-fixing properties of aluminum sulfate, litter treated with aluminum sulfate inhibits microbial phosphorous mineralization from organic matter (Warren et al. 2008). Although the literature review did not reveal problems associated with salinity of litter treated with aluminum sulfate, treated litter contains higher levels of soluble NH4+, and sulfur; thus, the salinity is likely higher than non-treated litter. However, salt damage to crops at normal agronomic application rates is likely low due to dilution factors (Sims and Luka-McCafferty 2002). Effects on bird health are positive, as ammonia accumulation causes lung irrigation to poultry (Walker and Burns 2000). Pathogen loads in the broiler house are reduced with aluminum sulfate, which combined with lower ammonia concentration in the air causes increased bird weight gain (Shah et al. 2006).

6. Are there any adverse impacts on biodiversity? (§205.200)

Aluminum sulfate reacts with water and naturally-occurring NH3 in the litter to form NH4+, thus stabilizing nitrogen and reducing NH3 gas volatilization to the atmosphere. In the soil environment, NH4+ is transient and is either rapidly taken up by plants, microbially transformed to NO32- which can be taken up by plants or lost to leaching, or anaerobically transformed by microorganisms to N2 and N2O which are lost to the atmosphere (Halvin et al. 2005). Although nitrogen is more persistent in the litter, there is no effect on cumulative soil nitrogen accumulation compared to non-treated litter, as aluminum sulfate does not alter the organic fraction of the total nitrogen.

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Category 3: Alternatives/Compatibility

1. **Are there alternatives to using the substance? Evaluate alternative practices as well as non-synthetic and synthetic available materials. [§6518(m)(6)]**

   Alternatives to litter amendments include management practices such as proper air exchange in barns, removing caked areas and keeping litter areas dry.

   TR LINES 569-581

   Clinoptilolite is a naturally-occurring aluminosilicate zeolite which can absorb ammonia, reducing volatilization to the atmosphere. The literature contains results of mixed efficacy for this material, with some reports of decreased ammonia in broiler house air, and other reports of increased atmospheric ammonia (Amon et al. 1997; Karamanlis et al. 2008; Shah 2006).

   Agricultural lime can be applied to litter between flocks to increase litter pH, chemically inducing volatilization of large quantities of ammonia. The volatized ammonia can then be removed by ventilation before birds are placed back in the poultry house. Removal of ammonia from litter in between flocks reduces ammonia concentration in air for the subsequent grow-out, but does not mitigate ammonia production during the grow-out compared to acidification products. Although lime does not decrease total atmospheric ammonia pollution like aluminum sulfate, phosphorous in the litter is stabilized by complexation with calcium at high pH to reduce eutrophication of natural water bodies after land application of the litter (Shah 2006).

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2. **In balancing the responses to the criteria above, is the substance compatible with a system of sustainable agriculture? [§6518(m)(7)]**

   Yes, but it is unclear if this substance is needed in organic agriculture as alternatives exist. The subcommittee would like to pose the following questions:

   1. Are there alternatives available to reduce Ammonia in poultry barns?
   2. Do the alternatives work in the area of reducing or eliminating Salmonella that could be present in barns?

Classification Motion: Move to classify aluminum sulfate as petitioned as synthetic
Motion by: Ashley Swaffar
Seconded by: Harriet Behar
Yes: 7 No: 0 Abstain: 0 Absent: 1 Recuse: 0

Listing Motion: Motion to add aluminum sulfate as petitioned at §205.603
Motion by: Ashley Swaffar
Seconded by: Jean Richardson
Yes: 0 No: 7 Abstain: 0 Absent: 1 Recuse: 0