Formal Recommendation
From: National Organic Standards Board (NOSB)
To: the National Organic Program (NOP)

Date: November 2, 2017

Subject: Petitioned Material - Elemental Sulfur

NOSB Chair: Tom Chapman

The NOSB hereby recommends to the NOP the following:

Rulemaking Action: X

Statement of the Recommendation:
The NOSB recommends the listing of elemental sulfur for use in livestock production to treat livestock and livestock housing.

Rationale Supporting Recommendation (including consistency with OFPA and Organic Regulations): Public comments indicated that producers, especially poultry producers, support the listing of this substance on the National List to help control mites. Producers also indicated that alternatives were not effective. The NOSB voted to add elemental sulfur to the National List based on public comment, and its compatibility with a system of sustainable agriculture.

NOSB Vote:

Classification Motion:
No classification motion was made since elemental sulfur has previously been classified as synthetic

Listing Motion:
Motion to add sulfur as petitioned under §205.603 for use in livestock production.
Motioned by A-dae Briones
Seconded by: Jessie Buie
Yes: 13 No: 0 Abstain: 2 Absent: 0 Recuse: 0

Outcome: Motion passed

National Organic Standards Board
Livestock Subcommittee Petitioned Material Proposal
Sulfur-elemental
August 1, 2017

Summary of Petition [Petition for Sulfur (PDF)]:
The petition is for sulfur to be used in livestock production as a livestock parasiticide. Sulfur (elemental) is currently allowed for use in the production of organic crops as an insecticide, for plant disease control, and as a plant or soil amendment. Sulfur is used as a pesticide (repellent for mites, fleas & ticks) for domestic livestock (chickens, turkeys, ducks, geese, game birds, pigeons, equine, cattle, swine, sheep, and goats and for use on dogs). Sulfur is dusted liberally and rubbed into feathers or hair. Sulfur us also used for treatment of listed animals/livestock living quarters to prevent mites, fleas, and ticks.

Summary of Review:

Category 1: Classification

1. Substance is for: **Livestock**

2. For HANDLING and LIVESTOCK use:
   a. Is the substance **Agricultural** or _X_ **Non-Agricultural?**
   Describe reasoning for this decision using NOP 5033-2 as a guide:

Sulfur is not being used as part of the finished product, but is a mineral used in an isolated form to be used as a pesticide.

   b. If the substance is **Non-agricultural**, is the substance **Non-synthetic** or _X **Synthetic?**
   Is the substance formulated or manufactured by a process that chemically changes a substance extracted from naturally occurring plant, animal, or mineral sources? [OFPA §6502(21)] If so, describe, using NOP 5033-1 as a guide:

Yes. Sulfur is an abundant element on the earth. Elemental sulfur is found in volcanic sites and salt domes. Sulfur was classically mined using the Frasch process in the U.S. as late as the 1920s. In the Frasch process superheated water is pumped into a sulfur deposit to melt the sulfur, which is then brought to the surface with compressed air. Sulfur produced by the Frasch process was 99.5% pure and required no further purification. In some locations sulfur is found near the earth's surface in sulfur craters. Here sulfur from the deposits is broken up and harvested with various kinds of mining equipment ranging from hand carried baskets to modern conveyor systems.

Sulfur is also found in petroleum, natural gas and fossil products from which it must be removed as a legal mandate to avoid the production of sulfur dioxide, a contaminant of the air. Hydrogen sulfide from petroleum refining and fossil fuels is converted to pure sulfur by the Claus process. The Claus process is used to produce the majority of sulfur available today. In a heating and cooling cycle, hydrogen sulfide recovered from fossil products is combusted to form water and elemental sulfur:

$$8\ H_2S + 5\ O_2 \rightarrow SO_2 + 7/2\ S_2 + 8\ H_2O$$

The addition of an aluminum or titanium catalyst permits the reaction of SO_2 formed during combustion with additional molecules of H_2S to yield sulfur and water:

$$2\ H_2S + SO_2 \rightarrow 3\ S + 2\ H_2O$$

In 2015, recovered elemental sulfur and its byproduct sulfuric acid were produced at 103 operations in 27 States. Total shipments were valued at about $933 million. Elemental sulfur production was 8.7 million tons; Louisiana and Texas accounted for about 52% of domestic production. Elemental sulfur was recovered, in descending order of tonnage, at petroleum refineries, natural-gas-processing plants, and coking plants by 39 companies at 96 plants in 26 States. Domestic elemental sulfur provided 64% of domestic consumption. About 11 million tons of sulfur were used in the US in 2015 (USGS, 2016).

3. For **LIVESTOCK**: Reference to appropriate OFPA category
   Is the substance used in production, and does it contain an active synthetic ingredient in the following categories: [§6517(c)(1)(B)(i)]; copper and sulfur compounds; toxins derived from bacteria; pheromones, soaps, horticultural oils, fish emulsions, treated seed, vitamins and minerals; livestock parasiticides and medicines and production aids including netting, tree wraps and seals, insect traps, sticky barriers, row covers, and equipment cleansers; or (ii) is used in production and contains synthetic inert ingredients that are not classified by the Administrator of the Environmental Protection Agency as inerts of toxicological concern?

   Sulfur does contain active sulfur compounds §6517(c)(1)(B)(i). Elemental sulfur is a sulfur compound. Its use in this petition is a livestock parasiticide. Sulfur is exempt from a residual tolerance (40 CFR 180.1236) and listed as a stabilizer for food use in 40 CFR 180.930.

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)]

Diatomaceous earth, kaolin and lard are natural substances that may be used for organic production. They are used with sulfur for dustbathing poultry to prevent lice and mite infestations. For example, equal parts lard and sulfur can be used to treat birds for the scaly-leg mite. Another treatment for depluming mites uses a combination of ¾ oz. sodium fluoride (not on the National List), 2 oz. sulfur, ½ oz. of household soap and 1 gallon of water. For lice, a dust bath containing sulfur and lime is effective (Rumball, 1927). In the treatment of the hen house for mites, lice and fleas, it is recommended to not only clean and coat surfaces, but to dust with a 3:1 combination of powdered slacked lime and sulfur (Herrick, 1915). When sulfur is used to treat honeybee colonies for mites, no changes in the hedonic performance of the honey is observed in comparison to a water spray control (Hosamani et al., 2007). Sulfur is not toxic to the honey bee (Kuan and Chi, 2007).

Windblown elemental sulfur from storage piles can result in heavy local deposits: 1 to 100 metric tons/hectare or more. These soils become completely barren with pH 1 to 2. Reclamation is possible by adding large amounts lime, $CaCO_3$ (Nyborg, 1978).

Sulfur as an element is not particularly flammable. However, combining sulfur with potassium chlorate can produce a very unstable, even explosive mixture (Tanner, 1959). Strong oxidizers such as perchlorates, peroxides, permanganates, chlorates can react with sulfur spontaneously cause a fire or explosion (NJ Health, 2011).

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)]

Elemental sulfur is found naturally and combined with iron and base metals and sulfide minerals. In petroleum, sulfur occurs in a variety of complex molecules. In natural gas sulfur is present as hydrogen sulfide. Sulfur is present in plants, animals and humans in a number of biological molecules. Recovered sulfur is the primary source of sulfur used for industrial applications. It is recovered from sulfur ores, during the refining of oil, and through the purification of natural gas (Komarnisky et al., 2003). Table 2 provides the sources of sulfur in the environment.

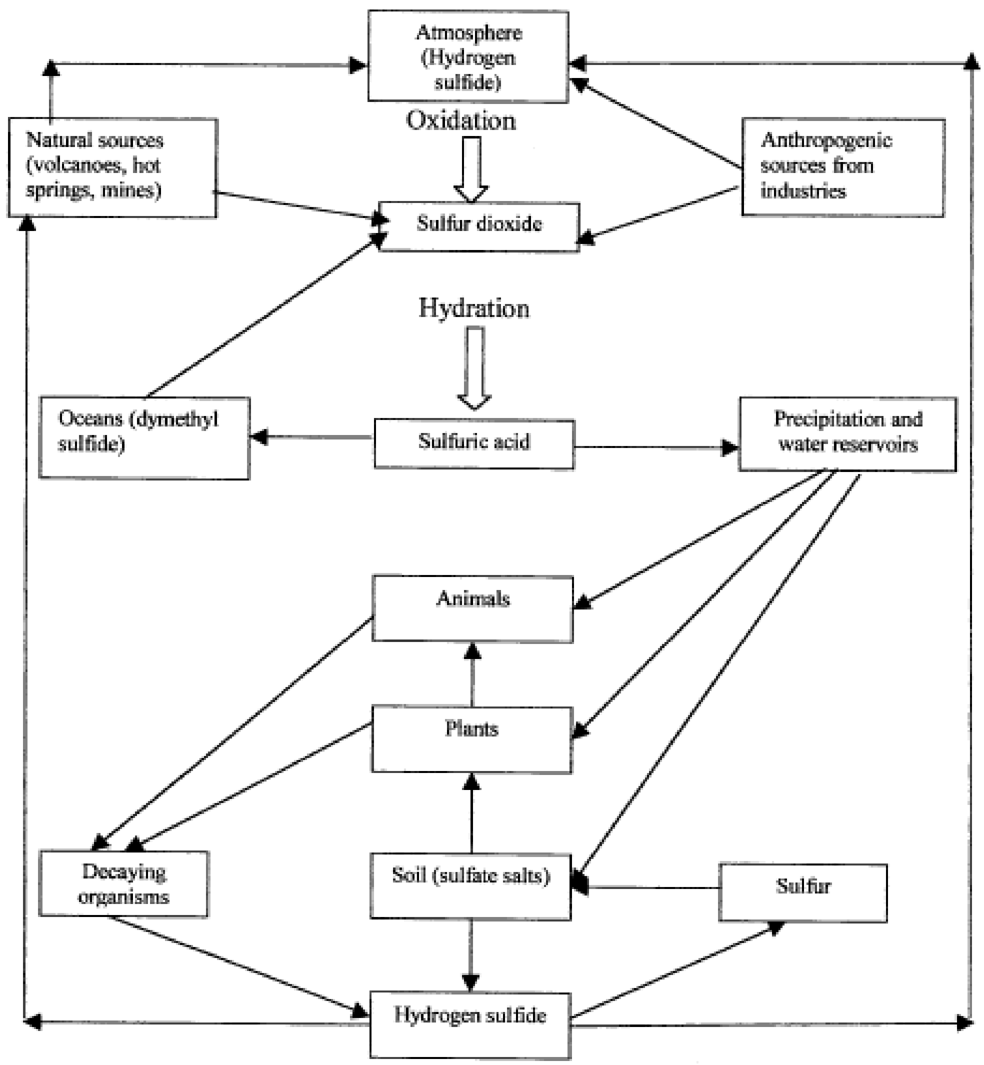

Fig 2. A simplified diagram of the natural sulfur cycle (Komarniskey et al., 2003)

Sulfur is essential for life in a range of concentrations as a part of or in combinations with other molecules. However, sulfur is known to cause polio encephalomalacia in ruminants and may inhibit arachidonic acid metabolism and platelet plasma membrane function in rabbits (Komarniskey et al., 2003). Consumption by ruminants of a high dietary percentage (>0.3%) of sulfur as elemental sulfur or sulfate can cause toxic effects. Sulfur bacteria in the rumen produce the poisonous gases, hydrogen sulfide and sulfur dioxide that eructate from the rumen and are absorbed through the lungs. Diets rich in sulfate can depress feeding. In spite of the liver's capability for detoxifying sulfide in the blood, extreme cases of sulfur toxicity can lead to death (Kandylis, 1984).

Elemental sulfur is insoluble in water. However, its solubility in organic solvents, such as methanol, is greater. Tests with zebrafish larvae showed sulfur toxicity at concentrations as low as 1%. A sulfur concentration that high may be achieved by dilution with methanol (Svenson et al., 1997).

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

Elemental sulfur is transported from mining, manufacturing and transshipping sites in pipelines and in tank cars in molten form. Molten sulfur has the potential to emit hydrogen sulfide gas, which 1) presents a safety hazard to those working in the vicinity and 2) an environmental hazard, since H_2S is very toxic (Sulphur Institute, 2013).

Pollution of the soils can take place where elemental sulfur is stored in the open. Wind eroding fine dust from sulfur blocks or grains stored in the open is deposited downwind of the manufacturing or storage facility. Over several years surrounding soils can become acidified with pH as low as 1. Acidification is the result of soil bacteria converting the sulfur to sulfuric acid. (Nyborg, 1978).

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

Current available U.S. Environmental Protection Agency toxicity studies and literature searches for elemental sulfur do not indicate any systemic toxicity associated with elemental sulfur exposure and no endpoints of toxicological concern have been identified. The acute toxicity of sulfur is low. Acute oral toxicity is a category IV hazard, i.e. fifty percent lethal dose (LD_{50}) is greater than 5000 milligrams (mg) per kilogram (kg) of body weight. Only the word caution or no signal word is required on the label for elemental sulfur for acute toxicity. Elemental sulfur is considered a category III hazard for dermal exposure and inhalation. For dermal exposure, LD_{50} > 2000 mg/kg ≤ 5000 mg/kg. Only the signal word caution is required. For inhalation, LC_{50} > 0.5 mg/L < 2.0 mg/L and the signal word caution must be on the label. Sulfur is an eye and skin irritant (category III, moderate irritation (erythema) at 72 hours), but is not a skin sensitizer. The EPA is satisfied that in most cases labels contain sufficient information about personal protective equipment and reentry and this information is generally followed by applicators (EPA, 2013a). The EPA's review of incident data indicates that both the relative number of reported incidents and the severity of reported health effects are low.

In livestock production, H_2S is a hazard to human health. This colorless toxic gas with a rotten egg odor is produced during the degradation of liquid manure stored in anaerobic conditions within agricultural livestock operations. In spite of regulatory limits for H_2S exposure of 1 ppm, levels as high as 9, 22 and 97 ppm have been reported for poultry, beef/dairy and swine production, respectively (Guarrasi et al., 2015). The contribution of elemental sulfur to the H_2S livestock production hazard for workers is negligible (EPA, 2013a).

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)]

Elemental sulfur is generally used for livestock insecticide applications in granular or finely powdered form. Liquids and mixtures are also in use. Small amounts of dusting sulfur or liquids find their way into soils or water, either as part of the manufacturing process, transport and storage or application to animals. None of these applications is recognized as an environmental problem (EPA, 1991b). In soils, sulfur is oxidized to sulfuric acid (H_2SO_4) by soil bacteria mostly of the genus *Thiobacillus*. Important factors for the rate of oxidation include 1) the fineness of the sulfur particles, 2) the resident population of *Thiobacillus* spp., 3) soil temperature and 4) soil moisture content. Powdered sulfur is quickly oxidized (Nyborg, 1978). In general there is very little effect on the vegetation, soil or the invertebrate population of the soil from small amounts of sulfur dust. Too much sulfur, e.g. from a sulfur storage or manufacturing facility will cause the pH of the soil to drop as low as pH 2.5 or lower. Although, H_2SO_4 in the soil can generally diffuse in the soil as a sulfate ion leachate, the introduction of high levels of sulfur can cause the loss of vegetative ground cover and affect a number of insect taxa (Carcamo et al., 1998). High sulfur contamination and subsequent acidification has a clear negative effect on earthworms, snails, and several ground beetle species. Among the beetles, ecological specialists are those most vulnerable to acidification, whereas ecological generalists are more resistant (Carcamo and Parkinson, 2001). Earthworms have an important influence on the sulfur turnover in the soil caused by their burrowing, feeding, digestion and egestion (Grethe et al., 1996).

Many species of sulfur reducing bacteria produce and metabolize elemental sulfur in a number of chemical transformations, both in soils and water. Quite a few of these have not yet been identified or characterized. In some cases, particularly in the absence of sufficient nitrate, hydrogen sulfide is produced in the metabolism of elemental sulfur. Hydrogen sulfide is responsible for a serious sulfur odor (Liang, 2016). Livestock operations frequently produce significant levels of hydrogen sulfide, notwithstanding from general practice rather than prevention or treatment for parasites using elemental sulfur (Guarrasi et al., 2015).

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

Sulfur has been used as a pesticide in the United States since the 1920s, and is currently registered for use as an insecticide and fungicide on a wide range of field and greenhouse-grown food and feed crops, livestock (and livestock quarters), and indoor and outdoor residential sites. Although sulfur has insecticidal and fungicidal properties when used as directed, it is also an abundant and ubiquitous element in the natural environment (Brown, 1982, EPA, 2013b).

Elemental sulfur is combusted at volcanic sites, and metabolized by sulfur bacteria to produce hydrogen sulfide that enters the atmosphere. Hydrogen sulfide in the atmosphere makes clouds more reflective producing a cooling effect on the earth. Sulfur in the atmosphere is involved in the prevention of global warming (Blake, 2007, Wingenter et al., 2007). Elemental sulfur is required for the existence of animal and plant life. Available evidence indicates that elemental sulfur is rapidly and extensively incorporated into the natural sulfur cycle via oxidation to sulfate and/or reduction to sulfide with subsequent volatilization (Lovelock, 1974; EPA, 2013b). The sulfur cycle can be simplified to four basic step: 1) mineralization of organic sulfur (e.g. methionine, cysteine) to an inorganic form (H_2S), 2) oxidation of sulfide, elemental sulfur and related compounds to sulfate, SO_4^{2-}, 3) reduction of sulfate to sulfide, 4) microbial immobilization of sulfur compounds and subsequent incorporation into an organic form of sulfur (Shaver, 2014; la Riviere, 1966). A simplified diagram of the natural sulfur cycle is shown in Fig 2.

Hydrogen sulfide entering the atmosphere reacts with oxygen to form sulfur dioxide. In water, sulfur dioxide forms hydrogen sulfite which in excess is responsible for generating acid rain, i.e. fossil fuels containing sulfur that are burned in the presence of air form sulfur dioxide that is subsequently absorbed into rain water. The pH range for acid rain is 4.2-4.4. Acidification of lakes, rivers and streams resulting from acid rain has led to the devastation of ecological communities and has put many on the brink of destruction. Industrial nations recognizing the environmental problems caused by acid rain have reacted by developing processes to remove sulfur from fossil fuels. Recovered sulfur is usually very pure (EPA, 2016).

Table 2 Occurrence of Sulfur in Nature			
Sources			
Natural			
	Volcanic deposits		Mixed with gypsum and pumice stone
			Realgar or ruby sulfur (arsenic sulfide)
	Subterranean deposits		
		Elemental	Sulfur Ore
		Metallic Sulfides	Acanthite, arsenopyrite, bismuthinite, chalcopyrite, cinnabar, cobaltite, copper pyrite, digenite, galena, iron, pyrite, molybdenite, pentlandite, sphalerite
		Non-metallic sulfides	Angelite, anglesite, barite or heavy spar, celestite, gypsum, thenardite
		Hot Springs	Sulfurous water
		Fossil Fuels	Coal, petroleum, natural gas
	Dietary		
		Food	Onion, cabbage, cauliflower, broccoli, oil of garlic, mustard, eggs
		Vitamins	Thiamine, pyridoxine (vitamin B6), biotin
		Amino Acids	Methionine, keto-methionine, cysteine, cystine, homocysteine, cystathionine, taurine, cysteic acid
		Preservatives	Sulfur dioxide
	Biological		
		Biochemicals	Proteins, lipoic acid, coenzyme A, glutathione, chondroitin sulfate, heparin, fibrinogen, ergothionine, estrogens, ferredoxin
		Microorganisms	Aerobic heterotrophic (most fungi and aerobic bacteria), *Desulfo vibrio* and *Desulfo tomaculum*, chemoautotrophic (e.g., thiobacillus), photoautotrophic (Chlorobium and Chromatium)
Industrial			
	Fertilizers		Phosphates and Ammonium sulfate
	Anthropogenic	Combustion of fossil fuels	SO_2, H_2S
from Komarnisky et al., 2003			

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)]

In livestock production, control of parasites living on the outside of animals (ectoparasites, e.g. mites) and in their housing should focus on excluding vectors such as wild animals and rodents from the production system. Pens and housing should be kept clean. In addition, caretakers should ensure that they do not transfer mites, ticks or lice from an infected population to a non-infected one. This can include placing baits and traps near the production facility for both the ectoparasites and their vectors, removing spilled feed, and monitoring rodent and wild bird activity. Buildings should be painted and sealed. Wood buildings must be treated to prevent infestation. In addition, livestock should be monitored regularly for infestations. Wild animal populations in fields, pastures, activity areas and forage should be monitored, and potentially infested animals should be sequestered from un-infested herds. Forage and pasture conditions should be monitored, since ectoparasite load is often affected by the extent of grass cutting. Livestock lines that are generally resistant to ectoparasite infestation should be chosen for breeding (Yakout and Wells, 2013).

Biological control of ectoparasites with pathogens such as nematodes, bacteria, fungi and viruses and predators that naturally prey on ectoparasites of livestock are potentially useful in ectoparasite management. For example, both parasitic wasps and the common bacterium, *Bacillus thuringensis* may be useful to protect sheep from various infesting flies, where the bacteria is also effective against lice. Some pathogenic fungi also selectively attack flies, lice and ticks (Wall, 2007).

2. **For Livestock substances, and Non-synthetic substances used in Handling**: In balancing the responses to the criteria above, is the substance compatible with a system of sustainable agriculture? [§6518(m)(7)]

Sulfur is currently used in crop production for pesticides on plants. During discussion, there was a question about the process of mining sulfur and whether that was detrimental to the environment. Much of the sulfur produced is a by-product of the petroleum, natural gas, and fossil industry. While there were few written resources discussing the human health effects of sulfur, current available U.S. Environmental Protection Agency toxicity studies and literature searches for elemental sulfur do not indicate any systemic toxicity associated with elemental sulfur exposure and no endpoints of toxicological concern have been identified. The acute toxicity of sulfur is low. In livestock production, H_2S is a hazard to human health. This colorless toxic gas with a rotten egg odor is produced during the degradation of liquid manure stored in anaerobic conditions within agricultural livestock operations. There are no alternatives except for the prevention of pests in the first place. Prevention methods include keeping livestock housing clean and using biological control (natural predators of pests). The information provided does not indicate a sulfur is incompatible with sustainable agriculture.

Subcommittee vote:
Motion to add sulfur as petitioned at §205.603
Motion by: A-dae Romero-Briones
Seconded by: Jessie Buie
Yes: 4 No: 0 Abstain: 2 Absent: 1 Recuse: 0

Approved by Ashley Swaffar, Subcommittee Chair, to transmit to NOSB August 29, 2017