THE ORGANIC CENTER™

April 5, 2021

Ms. Michelle Arsenault
National Organic Standards Board
USDA-AMS-NOP
1400 Independence Avenue, SW
Washington, DC 20250-0268

Docket: AMS-NOP-20-0089

RE: Crops Subcommittee - Ammonia Extract

Dear Ms. Arsenault:

Thank you for this opportunity to provide comments on the Crops Subcommittee Petitioned Material Discussion Document: Ammonia Extract.

The Organic Center is a non-profit organization with the mission of convening credible, evidence-based science on the environmental and health benefits of organic food and farming and communicating findings to the public. We are a leading voice in the area of scientific research about organic food and farming, and cover up-to-date studies on sustainable agriculture and health while collaborating with academic and governmental institutions to fill knowledge gaps.

Summary:

- ✓ Based on personal communication with researchers and our review of the scientific literature we conclude that ammonia and ammonia compounds resulting from "extraction" are chemically the same as synthetic ammonia products, and the environmental impacts of these products will depend on the chemical formula of the end-use product resulting from various extraction methods. That is, pure extract ammonia will interact with the environment differently from ammonia concentrate (pure extract + other minerals and organic matter).
- ✓ We offer a summary of science that shows how various forms of ammonia may impact soil health and emphasize the work that suggests negative impacts of adding Nitrogen Fertilizers will be reduced if applied simultaneously with other soil amendments.

We offer the following more detailed comments:

Synthetic ammonia/ammonium is chemically the same as extracted ammonia/ammonium.

Because "ammonia extract" manufacturing processes that capture and purify ammonia from anaerobic digestion or fermentation of agricultural feedstock such as animal manures are in the early commercialization process and their use is limited, there are few if any studies examining their impact on soil health and more research will need to be conducted in organic systems to understand the effects on certified organic soils.

However, because the final products in the extraction of pure ammonia (NH_3) and/or ammonium (NH_4^+) are chemically identical whether synthetically produced or non-synthetically extracted from a natural source, **the final ammonia and ammonium compounds should interact with crops and the environment similarly to synthetically produced ammonia and ammonium** according to several researchers (personal communication).

Professor Antonio Mallarino, Nutrient Management Research and Extension, Iowa State University: "If the product applied is ammonium, how it was synthesized is irrelevant from the perspective of its effects on soil properties and crop growth or nitrogen uptake, except perhaps for impurities that it may have which may vary with the process to produce it. These impurities usually are not an issue, are very low concentrations, and at normal rates applied should not be a problem even with repeated applications."

Professor John Sawyer, Department of Agronomy, Iowa State University: "if applied to soil as ammonium there would be no difference as the chemical formula is the same. There could be some initial differences if the original source were ammonia, urea, uric acid, manure, from digested manure or digested manure itself, etc. But once ammonium, then the microbial nitrification process would be the same and any long-term soil effects the same."

Different ammonia compounds result from different extraction methods

While the petition defines ammonia extract very broadly as "ammonia and ammonium compounds that have been isolated from processes other than the Haber-Bosch process," the main extraction methods described in the technical report, ammonia concentration and ammonia stripping, reflect two main outputs: one of ammonia concentrated amongst other excising compounds including organic matter and other minerals (from "ammonia concentration"), and one of pure ammonium salt (ammonia + acid/base; e.g. ammonium sulfate) solution or dry powder (from "ammonia stripping"). While extracted ammonia and ammonium components are chemically identical to their synthetic forms regardless of extraction methods, the resulting, end-use chemical formulas from these different extraction methods are different (pure extract + organic matter and minerals vs. pure extract) and as such, will interact with the environment differently.

In the instances where ammonia is isolated from anaerobic digestion processes, which is likely to be the common case since trapped ammonia can be a byproduct of generating biogas in anaerobic digesters of animal waste products, the end product will depend on whether the ammonia is stripped or concentrated from the waste product of digestion called digestate. Ghyselbrecht *et al.* 2018 states that "In some cases, however, only approximately 50% of the total organic dry matter is converted into biogas, indicating that the digestate still contains a substantial amount of organic matter." **This organic matter will be absent in a product resulting from ammonia stripping and therefore will differ in its breakdown and interaction with soil and soil organisms.**

The effects of ammonia extract on soil health

To determine environmental impacts of ammonia extract, the chemical formula of the ammonia product must first be defined, as effects depend on the fertilizer type and nature. Importantly, the chemical structure of ammonia from various extraction methods is the same as ammonia that is synthetically produced. There are many forms of synthetic ammonia and ammonium, and research shows that each has specific impacts on soil health. These differences in soil health impacts are often dependent on the individual components of synthetic formulations. We would therefore expect that ammonia extract would vary in its impacts on soil health dependent on its resulting, specific formulations and could not be lumped together in an overall assessment.

For instance, "ammonia concentration" can result in innumerable combinations and concentrations of ammonia salts, minerals, and organic matter depending on the starting feedstock used for the digestate as well as the concentration method (e.g. filtration versus evaporation, etc.), resulting in different types and concentrations of biofertilizers (e.g. liquid versus granular). Therefore, the interactions with plants, soil, and microbial communities will differ depending on the resulting end-use formula of the concentrate. In contrast, "ammonia stripping" results in specific ammonia compounds: some variation of ammonium salt depending on the acid used to trap (stabilize) ammonia gas at the end of the stripping process. Ammonia stripping from anaerobic digestion of animal manure, simply put, converts ammonium from organic matter ($NH4$) to ammonia ($NH3$) gas, which is then typically absorbed in an acid solution to create ammonium sulfate** or ammonium nitrate* (Baldi *et al.* 2018), though an organic acid like citric acid may also be used, resulting in ammonium citrate. Further description of the stripping process can be found HERE and a simpler explanation from a manure processing company is HERE.

Importantly, Sigurnjak *et al.* 2019 tested the end products from "ammonia stripping" from manure against synthetic ammonium fertilizer equivalents and **found no difference in characterization or performance between the stripped and synthetically produced fertilizers.**

While we recommend additional research, particularly in organic systems, on ammonia concentrates and extracts to understand their true impacts on soil health, initial hypotheses of ammonia from a stripping process may be derived from studies looking at synthetic ammonia products and their impacts **because the chemical structure of the ammonia is the same**.

From the scientific literature:

Science that measures the effects of biofertilizers in the form of **ammonia concentrate** (from anaerobic digestate) on soil health properties is currently lacking. One study conducted by Barzee *et al.* (2019) offered the first examination of various forms of ammonia concentrate, on crop yield and soil quality. This study compared synthetic-N fertilizer to two biofertilizers derived and concentrated from anaerobic digestate: liquid permeate (90% of original volume) and granular concentrate (10% of original volume). Soil fertility/quality metrics (pH and various mineral element concentrations) were measured, but not soil health indicators such as microbial activity/diversity or macrofauna abundance/diversity. The study found no significant differences in soil properties, however the authors state that the short time frame of the study cannot offer conclusions about long-term effects and more research needs to be conducted to understand the effects of biofertilizers of ammonia concentrate on soil and plant health properties.

Stripped ammonia and ammonia in synthetic nitrogen fertilizer are the same in chemical structure and expected to interact with the environment in similar ways, and because scientific research on the effects of stripped ammonia on soil health are limited, we mainly look to studies that examine the effects of synthetic fertilizer on the soil to represent stripped ammonia.

In general, the application of synthetic N-fertilizers alters soil properties like pH, organic matter content and soil microbial communities often with negative consequences. Additionally, nitrogen will mineralize at different rates ranging from days to years when derived from various types of amendments and applied to soils with varying amounts of soil organic carbon. The rate of mineralization will affect leaching or accumulation potential, ammonia and salinity concentrations, and microbial activity. When nitrogen mineralizes quickly (as in synthetic N fertilizers, and organic slaughter or liquid products) the potential for leaching increases and long-term fertility efficiency can decrease, while nitrogen from amendments like yard clippings and plant-based composts mineralizes more slowly, increasing the potential for accumulation in the soil (Lazicki *et al.* 2019). Studies indicate that carbon to nitrogen ratios in the soil and amendments will influence nitrogen mineralization with more carbon slowing the process and increasing the potential for long-term fertility, while reducing the potential for leaching (Mallory & Griffin 2007). A recent study by Singh 2018 suggests that if **N-fertilizers are applied at or below optimum rates and balanced with the application of additional nutrients in various forms, like organic manures, then the deleterious effects of long-term fertilization are reduced or eliminated**.

Studies on the impacts of long-term chemical fertilization show a reduction in the diversity of plants and microorganisms, negative impacts on the interactions of plants and soil microbes, and reduced capacity of the soil microbiome to cycle nutrients (Molina-Santiago & Matilla 2020, Pierik *et al.*, 2011; Cassman *et al.*, 2016; Wang *et al.*, 2018; Li *et al.*, 2019). Specifically, Wang *et al.* 2018 found that long-term application of N-fertilizers causes an abundance of bacterial groups responsible for the denitrification process, which causes the turnover of nitrogen to increase and results in greater nitrogen loss over time. Essentially, adding more nitrogen fertilizer results in a long term loss of nitrogen while altering other soil components, like decreasing soil pH and C:N ratio. When soil carbon and nitrogen are reduced in response to the application of chemical fertilizers, beneficial enzymatic activity of the soil also decreases (Ozlu *et al.* 2019).

Some studies have found negative impacts of specific fertilizers on soil health such as urea and the two most common products of ammonia stripping: ammonium sulfate and ammonium nitrate. For instance, Singh *et al.* 2013, stated that "urea is consumed by bacteria which convert it to (excrete) anhydrous ammonia and carbon dioxide. Anhydrous ammonia is highly toxic and kills organisms. If urea is applied to the soil surface, the gases quickly dissipate. However, in the presence of high air humidity anhydrous ammonia vapours form. These are heavier than air and can accumulate in low lying areas. If urea is incorporated into the soil, the ammonia gas reacts with water to produce ammonium hydroxide (NH4OH), which has a pH of 11.6. It is highly caustic and causes severe burns. This creates a toxic zone in the immediate vicinity of the applied urea that kills seeds, seedlings and soil dwelling organisms. Within a few days further chemical reactions in the soil release the ammonium ion NH4+, which then follows the same path as naturally occurring ammonium, with any excess nitrate created in this way leached into the environment."

When compared to organic amendments, synthetic ammonium nitrate reduced soil nematodes involved in nutrient cycling (Wang *et al.* 2006). And Singh *et al.* 2013 describes the interaction of ammonium nitrate as thus: "The nitrates are consumed by soil organisms, leached, or converted to nitrogen gas and volatized. The free oxygen produced through these processes oxidizes the organic matter of the soil and again causes a low level "combustion" (burning) of the organic matter. This is a purely chemical reaction which depletes the organic matter."

And "Ammonium Sulfate (NH4)2SO4 contains 24% sulfur. In the soil, [sulfur] interacts with water to produce sulfuric acid (H2SO4). Sulfuric acid has a pH of less than 1 and it is extremely toxic and kills organisms. Hydrogen ions released from the acid replace alkaline elements on the cation exchange sites, depleting the soil of nutrients. The free oxygen produced in this reaction oxidizes the organic matter of the soil and causes a low level "combustion" (burning) of the organic matter. This is a purely chemical reaction which depletes the organic matter. In calcareous soils (soil with excess calcium) the sulfuric acid reacts with calcium carbonate (CaCO3) to form gypsum (CaSO4). Gypsum is a salt and attracts water to itself and away from soil organisms and plant roots. In anaerobic conditions gypsum and water form hydrogen sulfide (H2S), which is a toxic gas," (Singh *et al.* 2013).

The negative consequences associated with the use of nitrogen fertilizers are more apparent when they're applied in isolation and using these fertilizers in simultaneous combination with other organic amendments or compounds can help reduce adverse effects by adding important carbon to the soil and balancing pH and beneficial microbial populations (Singh 2018).

Optimal range of ammonia concentration for crop use

The range of concentration that would be beneficial versus excessive (or ineffective), would depend on the extract's formula, the form of the end-use product (e.g. gas, liquid, solid), variables such as soil type, temperature, moisture content, and soil organic matter (Wang *et al.* 2018) and the crop type as nitrogen needs for different crops vary. For examples: anhydrous ammonia has about 82% nitrogen, while ammonium sulfate has 21%, and ammonium nitrate around 33%. Nitrate leaching has been found to vary across soil types. Sogbedji *et al.* (2000) found leaching to be higher on sandy loam soil than clay loam soil for corn production.

Glossary of terms: the most commonly used forms of ammonia/ammonium fertilizers

Anhydrous Ammonia- Anhydrous means without water. Ammonia is a gas that when compressed at atmospheric pressure and takes on a liquid form that can be injected into soil for fertilization (note that this form is still NH3 in its pure molecular formula, it is not combined with water in this form, though it is liquid). Once injected under the soil surface, the ammonia (NH3) expands into a gas and will combine quickly with any water present in the soil resulting in the production of ammonium (NH4). (See HERE and HERE for more information)

Aqua Ammonia- This form of ammonia is basically anhydrous ammonia mixed with a small amount of water that converts NH3 to NH4, which reduces the storage pressure of anhydrous ammonia, making it easier to handle. There isn't enough water in this solution to combine with all NH3 molecules, so there is still some free form (anhydrous) ammonia remaining in this solution that can escape into the air. This means that it must also be injected into the soil.

*Ammonium Nitrate- Ammonium nitrate (NH4NO3), a water soluble 50/50 mixture of ammonium and nitrate, is commonly used in fertilizers, pesticides and as an oxidizer in explosives. A concentrated liquid form to be used as a fertilizer is **formed from a reaction between ammonia gas and nitric acid**. Plants readily uptake nitrate in its water soluble form, while ammonium has to first be converted to nitrate by soil microorganisms. Essentially no ammonia volatilization occurs making this a more attractive fertilizer option than urea.

Ammonium sulfate- **Made from reaction between ammonia gas and sulfuric acid $(NH_4)_2SO_4$. It is an inorganic salt that is used as a dry-form fertilizer, particularly for alkaline soils that benefit from lowering the pH. Ammonium sulfate provides sulfur, an essential plant nutrient.

Diammonium phosphate- **Made from reaction between ammonia gas and phosphoric acid** $(NH_4)_2HPO_4$). Temporarily increasing soil pH, but over time decreases it, acidifying the soil. Phosphammite is the closest naturally occurring compound, which is related to bat guano.

Urea- Created in vitro via the liver which breaks proteins down into carbon dioxide, water and ammonia. Ammonia is toxic in vitro and so it is recombined with carbon and oxygen to produce urea (CH4N2O or also written as CO(NH2)2). Urea is often used as a component of fertilizer because it is a very nitrogen rich. Once in the soil, urea breaks down into ammonium (NH4) which is taken up by plants. Through oxidation, soil bacteria can break it down further into nitrates, which are also taken up by plants as nutrients. Urea passes through both ammonia and ammonium phases and when it is an ammonia gas, it can be released into the air.

Respectfully submitted,

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