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September 24, 2021

Ms. Michelle Arsenault
National Organic Standards Board
USDA-AMS-NOP
1400 Independence Avenue, SW
Room 2648-So., Ag Stop 0268
Washington, DC 20250-0268

RE: Ammonia Extract Impacts Review

Dear Ms. Arsenault:

Thank you for this opportunity to provide comments on the Crops Subcommittee Proposal: 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 products 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 resulting product from extraction.
- ✓ There is a lack of peer-reviewed science on environmental impacts of ammonia extract, so we must rely on scientific publications that examine effects of analogues including synthetic nitrogen fertilizers.
- ✓ We offer a summary of science that shows how various forms of ammonia may impact soil health with three main conclusions:
    1) The majority of available research has not been conducted in organic systems, which should influence outcomes of ammonia application.
    2) Impacts of ammonia on soil health and soil biodiversity are variable across studies, with no apparent trend of being beneficial.
    3) Research suggests that 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 there are several manufacturing processes that capture and purify ammonia, all are early in their commercialization with limited use, and are proprietary, there are few studies examining their impact on soil health.

However, because the final products in the extraction of ammonia (NH_3) and/or ammonium (NH_4^+) are chemically identical, whether synthetically produced or stripped from a natural source, **the final ammonia product should interact with crops and the environment similarly to synthetically produced 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:

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. 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 stripping and ammonia concentration, reflect two main outputs: one of ammonia concentrated amongst other excising compounds including organic matter, and one of pure ammonium salt solution (ammonia + acid/base; e.g. ammonium sulfate) or dry powder. The technical report describes two manufacturing methods to extract ammonia, however, technological advances will certainly result in more extraction methods, also with various end formulations.

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. Given that ammonia extract can be produced through a variety of methods, resulting in various formulations of ammonia and non-ammonia components, and that we expect that ammonia extract will vary in its impacts on soil health dependent on its resulting, specific formulations, we cannot lump all forms of "ammonia extract" into an overall assessment.

For instance, "ammonia stripping" generally results in specific ammonia compounds: some variation of ammonium salt depending on the acid used to trap 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 absorbed in an acid solution to create ammonium sulfate** or ammonium nitrate* (Baldi *et al.* 2018). 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 extracts to understand their true impacts on soil health, initial hypotheses of their soil impact may be derived from studies looking at synthetic ammonia products and their impacts because their chemical structures are the same.

<u>The majority of available research has not been conducted in organic systems:</u>
We agree with NOSB's position that "much more research regarding the use of these materials and of the soil health, plant health, and biological interactions is needed. There is conflicting information from studies on conventional soils and very little research conducted on organic soils."

Two comprehensive meta-analyses that that cover nearly 200 studies combined and have been presented to support that argument that ammonia extract might benefit soil health are based on science primarily conducted in non-organic systems (Geisseler and Scow 2014; de Graff *et al.* 2019). This is important because there is much scientific evidence indicating that organic and conventional soils can differ in their structure, fertility, and biological activity (Wittwer *et al.* 2021; Mullath *et al.* 2020). For instance, a national assessment of soil properties of conventional versus organic farms across the U.S. shows that overall, organic soil has higher levels of soil organic matter than conventional (mean 8.33% vs 7.37% respectively; Ghabbour *et al.* 2017). Because the impact of ammonia products on soil properties is affected by the initial soil properties before use, and because there are differences in baseline soil properties between organic and conventional soils, it is important that ammonia products are tested in organic farming systems to get an accurate understanding of their impacts.

<u>Effects of ammonia on soil health and soil biodiversity are variable:</u>
Several large scale meta-analyses that consider nitrogen cycling and impacts of nitrogen on soil health exhibit much variation in their results. For instance, when comparing nitrogen losses in conventional versus organic, Noll *et al.* (2020) found no difference between organic and conventional (suggesting that leaching is no greater in one type of system), however the authors also suggest that the high variability and high uncertainty in both systems doesn't allow them to make solid conclusions "on the statistical significance of these potential differences". Similarly, the meta-analysis by de Graff *et al.* (2019) also seems plagued by large variation in the data included in their analysis. For example, the study concludes that using <u>nitrogen fertilizers do not have a significantly negative impact on soil health including biodiversity</u>, yet the authors make several statements throughout the paper highlighting the variation in their data:

"Despite a plethora of studies showing that high rates of synthetic N inputs negatively impact soil bacterial communities ...our meta-analysis showed that high N fertilization rates had no significant negative effect on bacterial biodiversity."

"While the significant reduction in diversity with higher relative to lower N inputs confirms that fertilizer inputs can negatively affect bacterial diversity…our data underscore that responses are ***highly variable.****"*

"This variability can often be explained by among-study differences in site conditions…where fertilization may differentially affect other factors that mediate soil biodiversity such as soil synthetic properties, plant productivity, plant diversity, and soil organic matter content."

This variation means that, while there may be benefits to applying ammonia fertilizers to the soil, there are also enough detriments to wash out any strong signal of benefits, and **blanket conclusions cannot be made about the positive or negative impacts of ammonia fertilizer on soil health**. **It is important to consider the scientific literature that shows there are negative impacts.**

<u>Some science that shows negative impacts</u>:
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 2019).

However, de Graff *et al.* (2019) argues that nitrogen fertilizer application on farms with high levels of soil organic matter (SOM) will have less of a deleterious impact. This suggests that organic farms will be less impacted by the application of ammonia extract. We argue that this assumption cannot be made because, while research shows that organic farms tend to have more SOM than conventional, there is also variation within the organic system (e.g. 0.5% to 88.9% SOM in organic soil samples; Ghabbour *et al.* 2017).

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 nitrate and ammonium sulfate.

Urea can be found in raw-manure-based organic soil amendments, particularly in wet forms, and can have negative environmental impacts depending on how it is applied. 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."

It should be noted that support for the use of ammonium extract is often paired with the comparison against excess manure use in organic, suggesting the use of AE would reduce the presence of urea and potential build-up of phosphorus. We agree with points by the NOSB that suggest the systems-based approach that organic farmers must employ does not solely rely on animal manure for fertilizer and that the diversity of practices can balance soil nutrients like phosphorus over time. We offer additional references to strengthen this argument. For instance, Pires *et al.* 2018 conducted a national survey of organic farmers to learn about the use of biological soil amendments of animal origin (BSAAOs- including raw, untreated and treated manure, and compost) and found that manure-based soil amendments were not solely relied upon to manage soil fertility. Only 41.3% of organic farmers applied these soil amendments to forage or grain crops, 50% applied to crops typically cooked or processed, and 60% of organic farmers applied to produce crops to be consumed fresh.

Furthermore, the scientific literature does not indicate that organic farms consistently exhibit excess soil phosphorus. There is no comprehensive study that identifies farming regions with excess phosphorus based on soil sampling, however maps of phosphorus production from animal manure (e.g. CAFOs) and phosphorus application across the U.S. have been created (Bian *et al.* 2021, Spiegal *et al.* 2020). It is noteworthy that that the locations of excess phosphorus application do not match up with current organic hotspots, but rather more so with organic coldspots (see Marasteanu and Jaenicke 2018). And proper soil fertility management with practices like implementing diverse crop rotations and diversifying organic soil amendments can help reduce the P-loading (Cavigelli *et al.* 2013)

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."

"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).

Negative impacts of nitrogen fertilizers are reduced when applied with other soil amendments:
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). This is supported by Tully and McAskill (2019) who conducted a meta-analysis with only organic studies and found that using a combination of organic amendments had a larger benefit on soil health than using only one amendment type. And de Graff *et al.* (2019) also found that soil "bacterial diversity increased (~ 6%) when N was applied as an organic fertilizer or as a combination of inorganic and organic N fertilizers."

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.

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Respectfully submitted,

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