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

April 5, 2021

RE: Crops Subcommittee – Ammonia Extract (Discussion Document; Docket AMS-NOP-20-0089)

Dear Ms. Arsenault:

Thank you for this opportunity to provide comment on the National Organic Standards Board (NOSB) Crops Subcommittee's Discussion Document on Ammonia Extract. The dairy industry has licensed organic and conventional dairy farms in all 50 states and Puerto Rico, all doing their part to advance sustainable production of milk across the wide range of climatic and geographic differences. Part of that sustainability journey includes adopting new practices and technologies for continuous improvement in sustainability, making America's dairy farmers an environmental solution while providing wholesome and nutritious dairy products to the U.S. and the world. Ammonia extract from dairy cattle manure is a newer technology which can improve the sustainability of organic and conventional dairy farms. These comments are being jointly submitted by Newtrient LLC and the National Milk Producers Federation.

Newtrient LLC was formed by 14 leading dairy organizations and represents nearly all U.S. dairy farmers. Created to reduce the environmental footprint of dairy and make it economically viable to do so, Newtrient delivers innovative technology, manure-based product and market-driven solutions to create added value for farmers, communities and the environment.

The National Milk Producers Federation, based in Arlington, VA, develops and carries out policies that advance the well-being of dairy producers and the cooperatives they own. The members of NMPF's cooperatives produce the majority of the U.S. milk supply, making NMPF the voice of dairy producers on Capitol Hill and with government agencies.

U.S. Dairy Industry Commitment to Sustainable Production

The U.S. dairy industry's sustainability progress has been intimately tied to the long-standing USDA work in research, education, and economics. Due to the foundational research from and extension outreach by USDA going back many decades, producing a gallon of milk used 90 percent less land and 65 percent less water, with a 63 percent smaller carbon footprint in 2007 than in 1944.[1] In 2009 and reaffirmed in 2013, the U.S. dairy industry and USDA committed to increase sustainability by reducing GHG intensity 25% by 2020.[2] Preliminary analysis shows the goal is within reach with producing a gallon of milk in 2017

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[1] Capper,J.L., R.A. Cady, D.E. Bauman The environmental impact of dairy production: 1944 compared with 2007. 2009. Journal of Animal Science. 87:6 Pp 2160–2167. https://doi.org/10.2527/jas.2009-1781

[2] Memorandum of Understanding Between United States Department of Agriculture and The Innovation Center for U.S. Dairy. April 2013. https://www.usda.gov/sites/default/files/documents/usda-mou-innovation-center-us-dairy.pdf

requiring 30% less water, 21% less land, a 19% smaller carbon footprint and 20% less manure than it did in 2007.[3]

In 2018, the Innovation Center for U.S. Dairy convened leadership from across the industry to establish the U.S. Dairy Stewardship Commitment to document and demonstrate collective social responsibility progress in important areas including animal care, environmental stewardship, product quality and safety, workforce development and community contributions.[4] As part of its collective commitment to provide the world responsibly-produced dairy foods that nourish people, strengthen communities and foster a sustainable future, earlier this year the U.S. dairy industry set aggressive new environmental sustainability goals to become carbon neutral or better, optimize water usage and improve water quality by 2050.[5]

In 2010, the U.S. dairy industry launched the National Dairy FARM Program: Farmers Assuring Responsible Management™ to "*to show customers and consumers that the dairy industry is taking the very best care of cows and the environment, producing safe, wholesome milk and adhering to the highest standards of workforce development*."[6] Created by the NMPF in partnership with Dairy Management Inc., the FARM Program helps ensure the success of the entire industry by demonstrating that U.S. dairy farmers are committed to producing the best milk with integrity. The FARM Environmental Stewardship platform provides a comprehensive estimate of greenhouse gas emissions and energy use on dairy farms with a suite of tools and resources for farmers to measure and improve their footprint.[7] Today, 99 percent of the U.S. dairy farmers participate in the FARM Program with almost 80 percent by milk volume participating in the FARM Environmental Stewardship area.

To reach these 2050 goals, the U.S. dairy industry will need to identify technological and other advancements that can accelerate improvements, enabling nimble adaptation and focus on technology and practices that can be scaled for maximum impact. To meet these aggressive goals, we have mobilized through the Net Zero Initiative. The initiative is a partnership of the U.S. dairy community that seeks to unite the assets and expertise of trade, professional and industry organizations in a collaborative effort to create a path and growing portfolio of strategies and programs to achieve carbon neutrality, as well as significant improvements in water quality, through adoption of economically viable technologies and practices. USDA is an important part of this collaborative effort and the USDA Agriculture Innovation Agenda aligns with and will enhance our efforts.

Net Zero Initiative

Imagine a world where dairy is an environmental solution. Dairy presents solutions for today's nutrition and environmental challenges by providing accessible and affordable nutrition while sequestering carbon and improving soil health through improved land use systems; reducing greenhouse gas emissions through feed management, manure management and energy efficiency; and generating renewable energy that can cleanly power homes and businesses.

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[3] Capper, J.L., and R.A. Cady. 2020. The effects of improved performance in the U.S. dairy cattle industry on environmental impacts between 2007 and 2017. Journal of Animal Science. 98:1. Pp.1-14. https://doi.org/10.1093/jas/skz291
[4] Innovation Center for U.S. Dairy. 2018. The U.S. Dairy Stewardship Commitment. http://commitment.usdairy.com/
[5] Innovation Center for U.S. Dairy. 2020. New Environmental Goals Including Carbon Neutrality and Cleaner Water with Maximized Recycling by 2050. https://www.usdairy.com/sustainability/environmental-sustainability
[6] National Dairy FARM Program. 2020. https://nationaldairyfarm.com/
[7] FARM Environmental Stewardship. 2020. https://nationaldairyfarm.com/dairy-farm-standards/environmental-stewardship/

With this vision in mind, the Net Zero Initiative launched in 2020 as an industry-wide effort to accelerate voluntary action on farms to reduce environmental impacts by making sustainable practices and technologies more accessible and affordable to U.S. dairy farms of all sizes and geographies. This is achievable through research, on-farm pilots, development of manure-based products and ecosystem markets, and other farmer technical support and opportunities. The primary expected outcomes include 1) the collective U.S. dairy industry advances to net zero carbon emissions and significant improvements in water use and quality, 2) in addition to nutrient-dense foods and beverages, dairy farms provide products and services that enable other industries and communities to be more sustainable, and 3) farmers are able to realize the untapped value on-farm, making the system of continuous improvement self-sustaining.

Ammonia Extract

The NOSB has requested information on several scientific questions about the use of ammonia extract on soil health and crop production. Newtrient LLC and NMPF have worked with consultants Jerry Hatfield, Ph.D. (retired USDA Agricultural Research Service) and Bert Bock, Ph.D. (President, BR Bock Consulting, Inc.) to address these scientific questions. Their white paper, "*The Role of Manure-Based Aqua Ammonia for Expanding Organic Crop Production and Improving Soil Health*" addressing the NOSB scientific questions, is appended to these comments in Appendix A. The white paper presents compelling information about the benefits of manure-based ammonia extract on soil health and crop production.

With the potential benefits of manure-based ammonia extract defined, the NOSB should focus on the important process of determining whether an ammonia extract is synthetic of non-synthetic. The Organic Foods Production Act of 1990 (and subsequent amendments) defines "synthetic" for the USDA National Organic Program as:

> "*A substance that is formulated or manufactured by a chemical process or by a process that chemically changes a substance extracted from naturally occurring plant, animal, or mineral sources, except that such term shall not apply to substances created by naturally occurring biological processes*."[8]

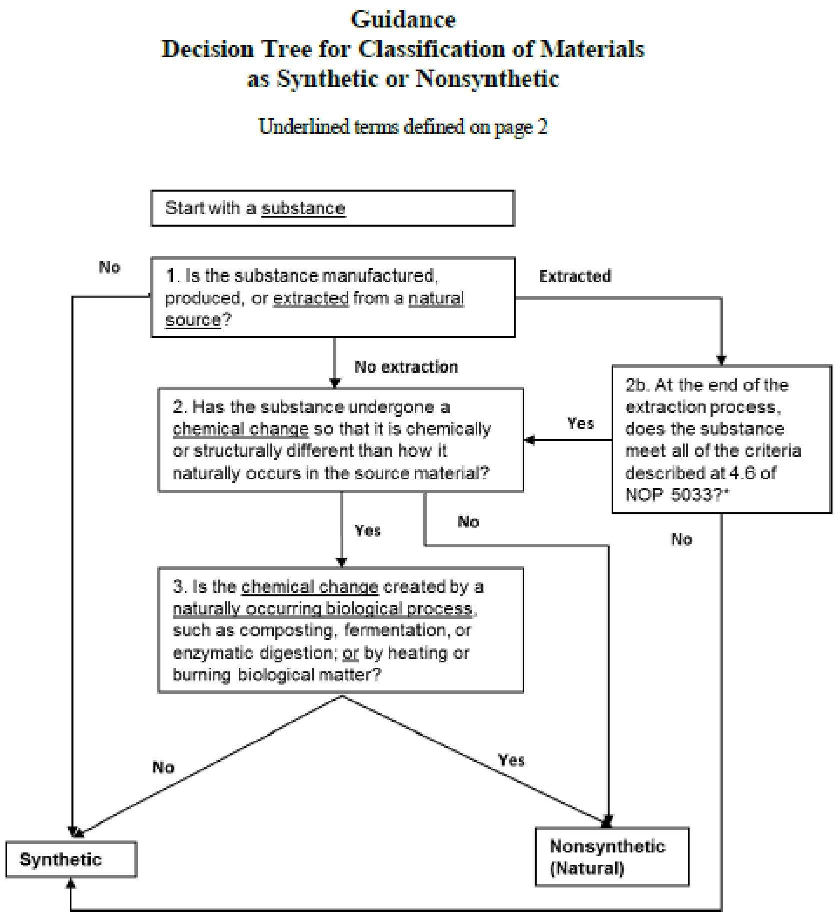
The National Organic Program ***Guidance of Classification of Material*** (Section 5033, 4.6 Extraction of Nonorganic Materials) states:

> "*Some materials are produced using manufacturing processes that involve separation techniques, such as the steam distillation of oil from plant leaves. Separation and extraction methods may include, but are not limited to, distillation, solvent extraction, acid-base extraction, and physical or mechanical methods (e.g., filtration, crushing, centrifugation, or gravity separation).*
>
> *For purposes of classification of a material as synthetic or nonsynthetic, a material may be classified as nonsynthetic (natural) if the extraction or separation technique results in a material that meets all of the following criteria:*
> - *At the end of the extraction process, the material has not been transformed into a different substance via chemical change;*

[8] 7 USC 94 Organic Certification § 6502 Definitions (22). https://www.law.cornell.edu/uscode/text/7/6502#22

- *The material has not been altered into a form that does not occur in nature; and*
- *Any synthetic materials used to separate, isolate, or extract the substance have been removed from the final substance (e.g., via evaporation, distillation, precipitation, or other means) such that they have no technical or functional effect in the final product."*[9]

Finally, the National Organic Program provides this rigorous, science-based, decision tree to help people understand if a product is Synthetic or Non-Synthetic:[10]



Given the above information and National Organic Program regulations and policies, we believe there is the appropriate structure for the NOSB to determine if a manure-based ammonia extract is non-synthetic and thus allowable for organic production.

Conclusions

We believe that science demonstrates the soil and crop benefits of ammonia extract from dairy cattle manure as a nitrogen fertilizer, and therefore, request that the NOSB follow the National Organic Programs' own rigorous, science-based, decision tree when determining if an ammonia extract is

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[9] USDA. NOP 5033. Guidance Classification of Materials. 2016. https://www.ams.usda.gov/sites/default/files/media/NOP-5033.pdf

[10] USDA. NOP 5033-1. Guidance Decision Tree for Classification of Materials as Synthetic or Nonsynthetic. 2016. https://www.ams.usda.gov/sites/default/files/media/NOP-Synthetic-NonSynthetic-DecisionTree.pdf

Synthetic or Non-Synthetic. We believe that ammonia extracts determined to be Non-Synthetic should be allowed to be used as nitrogen fertilizer in the National Organic Program. One of the greatest opportunities that exists for dairy farmers is their ability to provide real solutions to many of today's biggest environmental challenges like carbon emissions, soil health, water quality and water quantity. Embracing new practices and technologies is key to making America's dairy farmers an environmental solution while providing wholesome and nutritious dairy products to the U.S. and the world.

We look forward to continuing to work with the NOSB and USDA on these important sustainability efforts.

Sincerely,

Chris Kopman

Chris Kopman
General Manager
Newtrient LLC

Jamie Jonker, Ph.D.
Vice President Sustainability & Scientific Affairs
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APPENDIX A

The Role of Manure-Based Aqua Ammonia for Expanding Organic Crop Production and Improving Soil Health

Introduction

Two major constraints to expansion of sustainable organic crop production in the United States are an inadequate supply of organic nitrogen fertilizers (CSANR, 2017) and the ratio of N to P in organic fertilizer sources, including manure. When manure and most other organic fertilizer sources are applied to supply the crop N requirements, more P is applied than removed by the crop (Dairy Business News, 2021). That results in soil P levels building up to a level that can lead to P runoff and adverse effects on water quality. This can be solved by having more organic fertilizers that contain N and no or less P. On the other hand, individual dairy farms often have more manure N than can be used in an environmentally sustainably way on-farm, but the low concentration of N in the manure is a hindrance to export off farm. Aqua ammonia extracted from manure is sufficiently concentrated (in the 10% range) that it can be economically transported off-farm to alleviate surplus N on dairy farms and at the same time alleviate organic N fertilizer supply constraints off-farm. Since aqua ammonia contains no P, other organic fertilizers can be used to supply the optimum amount of P and some of the N for crops, and aqua ammonia can be used to provide the amount of supplemental N required. This will avoid the soil P buildup that normally occurs when organic fertilizers are applied on an N basis. This is a win-win scenario for both sustainable organic crop production and dairy farms. Of course, this win-win scenario can only be implemented if manure-based aqua ammonia is approved for use in organically certified crop production and the purpose of this document is to help make a case for approval.

A key question that has been asked is: what is the effect of aqua ammonia on soil health? There is a perception, not supported by science, that anhydrous ammonia has long-term adverse effects on soil health and this perception carries over to aqua ammonia. Below, we provide data indicating that anhydrous ammonia applied over many years at agronomic rates does not have long-term adverse effects on soil chemical, physical, or biological properties related to soil health.

Chemical Characteristics of Injected Aqua Ammonia Bands

Aqua ammonia is ammonia dissolved in water to form ammonium hydroxide.

$$\underset{\text{Ammonia}}{NH_3} \quad + \quad \underset{\text{water}}{H_2O} \quad \rightarrow \quad \underset{\text{aqua ammonia (ammonium hydroxide)}}{NH_4OH}$$

Aqua ammonia has a much lower vapor pressure than anhydrous ammonia but the vapor pressure is high enough that the aqua ammonia has to be injected below the soil surface to prevent volatilization of ammonia; however, aqua ammonia can be injected at a shallower depth than anhydrous ammonia without losing volatilized ammonia. Conventional injection at the base of knives results in compact, concentrated bands in the same way as injection of liquid dairy manure. These bands are similar in geometry to anhydrous ammonia bands injected at the base of injection knives. The Dairy Research Institute is evaluating options for achieving more diffuse bands but let's first consider the geometry and chemistry of compact, concentrated bands.

The two key factors in aqua ammonia bands that potentially adversely affect soil biology are the concentration of <u>ammonia in soil solution</u> and the pH. Also, high pH can dissolve small amounts of soil organic matter.

Aqua ammonia is a base which means it increases soil pH, the extent determined by amount added and the capacity of the soil to resist increases in pH. The soil pH in the injection zone determines the fraction of ammoniacal N (NH_4^+ + NH_3) in soil solution that is present as ammonia (NH_3). For example, at pH 8.0, 5% of the ammoniacal N is ammonia and at pH 9, 36% of the ammoniacal N is ammonia.

The pH and concentration of ammonia in soil solution vary greatly with distance from the center of the bands and are strongly influenced by the following factors illustrated for an N rate of 120 lb/Ac applied on a 30-inch spacing in a sandy clay loam soil:

1. Total ammoniacal N (NH_4^+ + NH_3) in the band (Figure 2, top-left).
2. Portion of ammoniacal N sorbed as $NH4^+$ [i.e., held on the surfaces of negatively-charged soil particles, known as the cation-exchange capacity (CEC), and not in the soil solution], Figure 2, top-left. The rest of the ammoniacal N is in the soil solution between soil particles.
3. Portion of ammoniacal N (NH_4^+ + NH_3) in soil solution as ammonia (NH_3), Figure 2, bottom-left. This depends on pH which varies with distance from the center of the injection bands (Figure 2, top-right). It is only the ammonia in soil solution that can potentially temporarily adversely soil biology.

Note in the lower-right graph that there is virtually no ammonia in soil solution outside a 1.5 inch radius from the center of the bands and that the concentration of ammonia is much lower with a CEC of 27 than 14. This inner portion of aqua ammonia bands is the portion that has the greatest potential for adversely affecting soil biology. The inner 1.5-inch portion of aqua ammonia bands spaced 30 inches apart comprises 3.9% of the top 6 inches of soil on a volume basis. Furthermore, these highly localized increases in pH and ammonia are transitory and dissipate in a matter of days to weeks. Literature discussed later indicates that these localized and transitory effects do not generally have long-term adverse effects on soil health.

The high pH and ammonia levels in soil solution are transitory because conversion of ammonium to nitrate occurs in days to weeks and lowers the ammonia levels to virtually zero and the pH to lower than before for application (discussed in a later section). The conversion of ammonium to nitrate progresses inward from the periphery of the bands.

The above example is for 120 lb N/Ac. We envision that the typical rate of aqua ammonia used to supplement the N in other organic fertilizer sources that provide P and K will generally be significantly less than 120 lb N/Ac, resulting in significantly lower soil pH and ammonia levels in injection bands than illustrated in Figure 2. Also, the soil pH and ammonia levels in injection bands can be lowered by using a narrower knife spacing or by applying more diffuse bands.

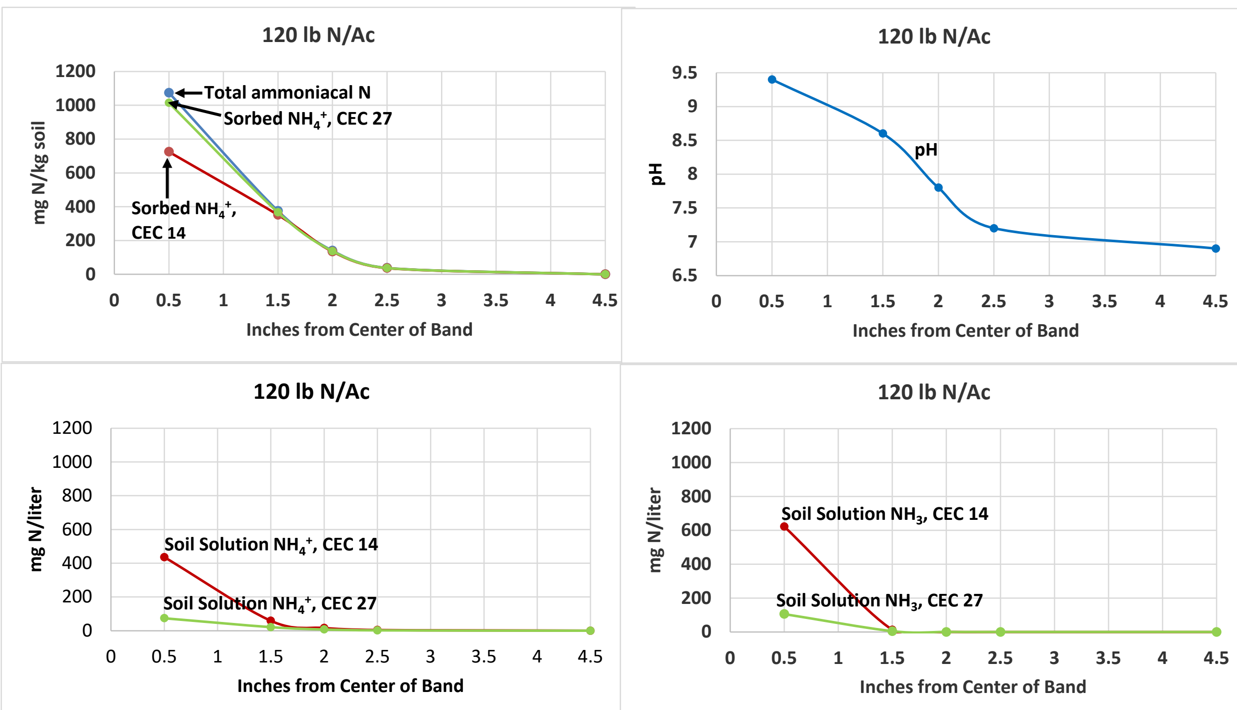

Figure 2. Effects of distance from center of bands, CEC, and pH on the concentration of various forms of ammoniacal N in aqua ammonia bands.[1/]

[1/](Total ammoniacal N and pH based on McIntosh and Frederick, 1958; other lines calculated based on ammoniacal N and pH from McIntosh and Frederick, 1958, and ammonium sorption curves and calculation procedures from Venterea et al., 2015).

Chemical Characteristics of ammoniacal N in Liquid Dairy Manure

For perspective compared with aqua ammonia, the chemical properties of bands of injected liquid dairy manure are characterized below. The increase in pH and ammonia level with increasing rate in of these bands is not greatly different than the chemistry of aqua ammonia bands. The implication is the effect aqua ammonia bands on soil biology is not expected to be much different from the effects of injected liquid dairy manure bands.

Typically, about one-half of the N in liquid dairy manure is ammoniacal N that is produced from the decomposition of urea in the urine (Cornell Agronomy Fact Sheet 4). The enzyme that facilitates decomposition of urea is readily available in manure and the urea converts quickly according to the following reaction:

Urea ➔ $2NH_4^+$ + CO_3^{-2} (Koelliker and Kissel, 1988)
ammonium carbonate

It is the ammonium carbonate released from urea that increases the pH and ammonia that is lost when liquid dairy manure is applied on the soil surface. On a per pound N basis, the ammonium carbonate produced from the decomposition of urea increases soil pH about the same as aqua ammonia until the pH reaches about 8; above pH 8, the carbonate produced from urea starts to react in a way that partially restricts further increases in soil pH and ammonia. The point is that bands of injected liquid dairy manure result in temporarily high pH and ammonia levels in much the same way as bands of injected aqua ammonia. The increase in soil pH with addition of urea (a surrogate for the ammoniacal N in liquid dairy manure) and aqua ammonia is illustrated in Figure 3 for a fine sandy loam soil. The increase with urea is the same as for aqua ammonia until the soil pH reaches about 8 and then aqua ammonia increases soil pH more than the urea with increasing application rate of N. With the relatively low application rates envisioned for aqua ammonia as a supplemental N source, we expect injected aqua ammonia to result in about the same pH and ammonia levels as injected liquid dairy manure.

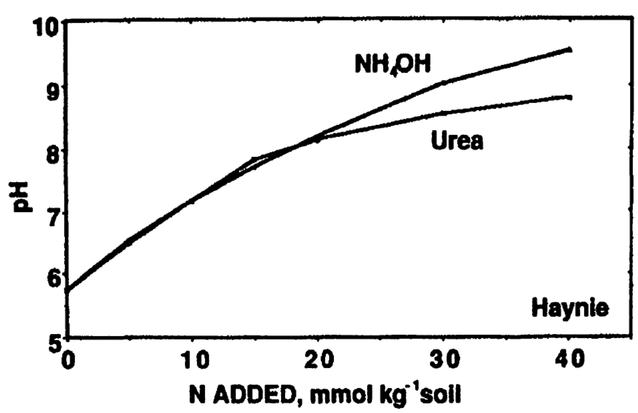

Figure 3. Illustration that aqua ammonia (NH_4OH) and urea have the same effect on raising soil pH up to about pH 8 and then aqua ammonia increases soil pH more than urea (Kissel et al., 1988).

Amount of Acid Ultimately Produced

Aqua Ammonia

For aqua ammonia, the amount of acid produced is:

$$NH_4OH \rightarrow NH_4^+ + OH^- \rightarrow NO_3^- + 2H^+ + OH^- \rightarrow NO_3^- + H_2O + H^+ \text{ (i.e., a net of } 1H^+/N)$$

(Kissel et al., 2020)

Aqua ammonia contains one OH^- and produces 2 H^+ when NH_4^+ is converted to NO_3^-. Therefore, the net long-term effect of applying aqua ammonia is production of $1H^+/N$. This means that aqua ammonia increases the pH of compact bands initially and then ultimately reduces soil pH to below the starting point after the NH_4^+ converts to NO_3^-. This is illustrated in Figure 3. By 5 weeks after application, pH had stabilized at the two sampling points furthest from the center of the band, indicating that conversion of ammonium to nitrate was close to completion; at those distances, pH was lower than the control. Conversion of ammonium to nitrate apparently was not complete after 8 weeks at the 2 sampling points closest to the center of the band and pH was still higher than the control. Theory indicates that the pH at these distances would ultimately be lower than the control with no ammonia added.

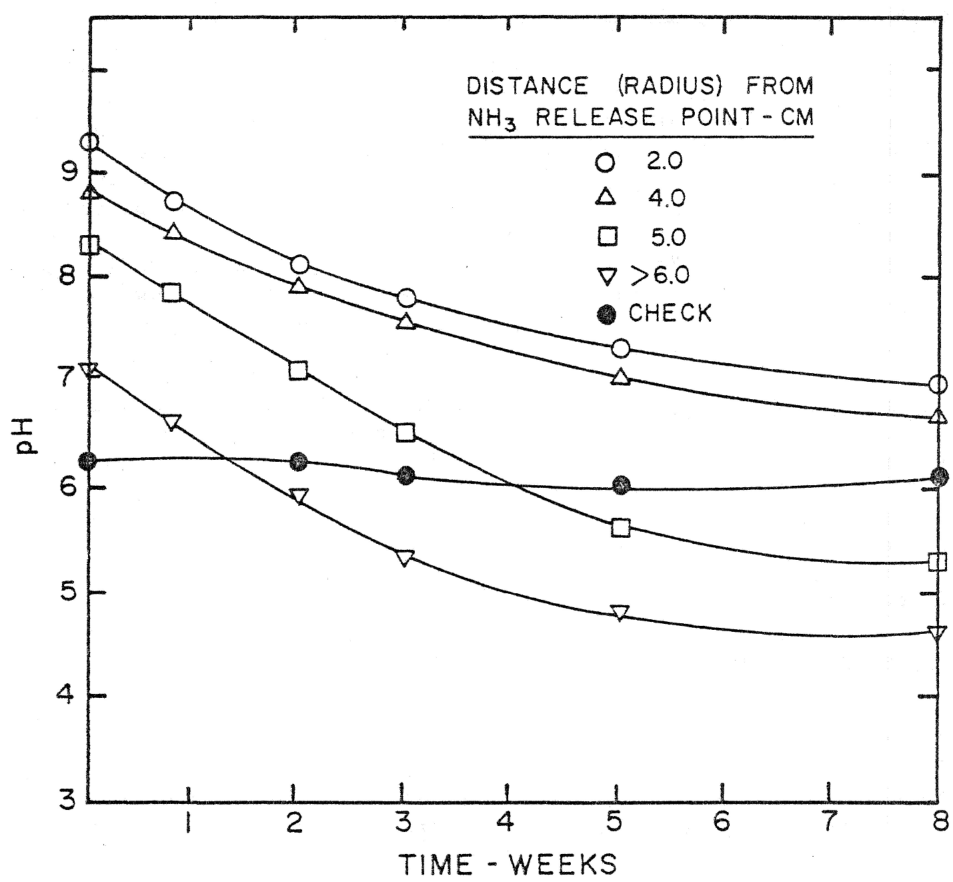

Figure 3. Change in pH following banded ammonia application as function of distance from center of the band and weeks after application (Parr and Khasawneh, 1968)

Ammoniacal N in Liquid Dairy Manure

The acid produced due to conversion of urea-derived ammoniacal N in liquid dairy manure to nitrate can be expressed according to the following equations, starting with urea:

Urea ➔ $2\ NH_4^+ + CO_3^-$

$2\ NH_4^+ \rightarrow 2NO_3^- + 4H^+$

$4H^+ + CO_3^- \rightarrow CO_2 + H_2O + 2H^+$ (i.e., $1H^+/N$) (Kissel et al., 2020)

Therefore, the ammoniacal N in dairy manure produces the same amount of acidity per unit N as aqua ammonia.

Representative Long-Term Studies

Next, we include summary results from some key long-term studies representative of effects of injected anhydrous ammonia and aqua ammonia on soil properties that affect soil health. Anhydrous ammonia is used as a surrogate for aqua ammonia because the chemical properties of injected bands of the two N sources are similar and there are more data available for anhydrous ammonia.

Solubilization of Soil Organic Matter

High concentrations of strong bases are known to solubilize portions of soil organic matter. Aqua ammonia is a weak base but potentially can solubilize small amounts of soil organic matter at sufficiently high concentrations. Tomasiewicz and Henry (1985) evaluated effects of anhydrous ammonia injected in compact bands on solubilization of soil organic matter in ten soils, both at field capacity and permanent wilting point moisture contents. These evaluations were at 60, 120, and 240 lb N/Ac rates. Effects were measured at 0-1 inch, 1-2 inch, 2-3 inch, and 3-4 inch distances from the center of bands. Samples were taken 1 and 35 days after application. One day after application, in the 0-1 inch segment, 0.3 to 4.6% of the organic matter was solubilized and the 4.6% reduction occurred in only one soil. In the 1-2 inch segment, the range was 0.0 to 3.0% of organic matter solubilized. In the 2-3 inch segment, the range was 0.0 to 0.6%, and in the 3-4 inch segment, there was no effect. The authors calculated that assuming a 12-inch knife spacing and a 6-inch depth of soil, 4.6% of the soil would be within 1 inch of the injection point., 13.1% would be between 1 to 2 inches and 21.8% would be between 2 to 3 inches. Thirty-five days after application, less than 1.2% of organic carbon was solubilized in all cases. The authors concluded that the amount of soil organic matter solubilized would be insignificant if expressed on a total soil basis.

Soil Microbial and Biochemical Properties

Biederbeck et al. (1996) reported on the long-term effects of 10 years of injecting anhydrous ammonia and urea on a 12-inch spacing, a depth of 4 inches, and at rates of 40, 80, and 160 lb N/Ac/yr. They measured effects 3 days before the tenth-year application and 6 and 26 days after the tenth-year application. Soils were sampled at 0-3 inch and 3-6 inch depths. Tillage was at less than 3-inches deep so as to not disturb the bands of injected fertilizer. Soil was sampled in the bands at 0-3 inch and 3-6 inch depths. Soil samples were not taken at smaller incremental distances from the center of the bands, so pH and ammoniacal N concentrations close to the center of the bands are not known. A wide range of soil microbial and biochemical properties was measured. A key finding was that wet aggregate stability was not affected by the urea and anhydrous ammonia treatments and that with injected N rates less than 80 lb N/Ac, deterioration of soil quality should be minimal. It is our expectation that the amount of aqua ammonia required to supplement organic fertilizer that supply P an K will usually be 80 lb N/Ac or less.

Soil Chemical and Physical Properties

Darusman et al. (1991) reported on soil properties after 20 years of fertilization with different N sources. Anhydrous ammonia was injected on an 18-inch spacing at a depth of 6 inches and ammonium nitrate, urea, and urea-ammonium nitrate solution were surface applied and incorporated with tillage. These applications were in the spring. A control with no N was included. These treatments were compared for 20 years at 4 locations in Kansas starting in 1969. The initial N rate at each site was 200 lb N/Ac but was reduced to 150 lb N/Ac at one site beginning in 1973 and was reduced to 100 lb N/Ac at another site after 1980. After the spring applications, the plots were disked at approximately a 4-inch depth, so the upper part of the ammonia retention zone likely was disturbed each year. No lime was applied and as would be expected, all N sources decreased soil pH relative to the control. In practice, these reductions in soil pH would be corrected with lime. Except for pH, there were no detectable differences among N sources regarding soil chemical properties, including soil organic matter. Regarding soil physical properties, including bulk density, clod density, and compatibility, there were no differences among N sources or differences between the control and N sources except for geometric mean diameter (GMD) of soil aggregates. At the 3-6 inch depth, the GMD was 0.95 for the control and 1.58 for the N treatments (significant difference at the 0.05 probability level). At the 8-12 inch depth the trend was reversed; the GMD was 1.35 for the control and 0.96 for the N treatments (significant difference at the 0.05 level). This study was selected for comment because it is long term and compares injected anhydrous ammonia (comparable to injected aqua ammonia) with three N sources that were broadcast and incorporated with tillage (no effect of concentrated bands). No difference between anhydrous ammonia and the other three N sources provides strong evidence that the initially harsh chemical conditions in the center of anhydrous ammonia bands are transient and don't have adverse long-term effects on chemical and physical properties of soil, including those associated most closely with soil health such as soil organic matter, bulk density, compatibility, clod density, and GDM of soil aggregates.

In addition to the long-term studies overviewed above, we recommend the review article entitled: The Effect of Anhydrous Ammonia on Soil (Henry et al., 1978).

Soil Health Responses to Ammonia

Efficient crop production and sustainability are dependent upon high quality soils and nutrient supplies (Drinkwater and Snapp, 2007). Soil health responses to organic or synthetic sources of nutrients are not uniform and dependent upon the soil, management history, tillage practice, cropping system, climate, and the amount of nutrient applied to the soil. Across the peer-reviewed literature, there is a large amount of disparity in terms of the comparisons between organic and inorganic sources and meta-analyses which summarize the results across a large number of studies reveal the inconsistences and responses across studies. One aspect is that both field and controlled environment studies are often short-term and nutrients applied in a manner not typical of fertilizer placement. One of the first comparisons across multiple studies was conducted by Bünemann et al. (2006) where they compared inorganic sources (ammonium nitrate, ammonium sulfate, calcium nitrate, urea, and several forms of phosphorus) to organic sources (animal manures, composts, or biosolids). They characterized the responses as being short-term (within the growing season) and long-term (more than one growing season) and whether the impact on soil organisms was direct (increased amount or activity after removal of nutrient limitations, decreased activity due to high nutrient availability or decreased amount and/or activity due to toxicity) and indirect effects (change in pH, change in soil physical properties, e.g., aggregation, porosity, or change in productivity, residue inputs, and soil organic matter levels). The effect of mineral fertilizers depends upon the biological organism being evaluated in the study and many field experiments show no response of microbial biomass or earthworms to mineral fertilizers (Bünemann et al., 2006). Moore et al. (2000) show the complexity of the problem because microbial biomass was related to organic C levels in the soil which were induced by different crop rotations. The variable impacts observed in different studies require an analysis of the system being compared. Bünemann et al. (2006) concluded that additions of mineral fertilizers show variable results on soil organisms while additions of organic materials show either no effect or a positive effect.

Conclusion

The above assessment indicates that a temporary increase in soil pH and ammonia levels develops in the inner portion of aqua ammonia bands representing a small portion of the top six inches of soil. These conditions subside in days to weeks due to conversion of ammonium to nitrate, and the impact on health of the overall soil is not detectable in longer-term studies.

Manure-based aqua ammonia holds great promise for expanding the supply of organic nitrogen for United States organic crop production and facilitating further growth of that industry. Manure-based aqua ammonia also holds great promise for enabling organic crop producers to provide adequate N without over-applying P. These two benefits will improve the sustainability of United States organic cropping systems.

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