

Ammonia Extract

Crops

Identification of Petitioned Substance

Chemical Names:

Ammonia
Nitrogen trihydride
Azane
Ammonium
Ammonium ion
Ammonium cation
Azanium

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20
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Trade Names:

N/A

CAS Numbers:

7664-41-7 (ammonia)
14798-03-9 (ammonium)

Other Codes:

EC No. 231-635-3 (ammonia)
ICSC No. 0414 (ammonia)
RTECS No. BO0875000 (ammonia)
UNII No. 5138Q19F1X (ammonia)
UNII No. 54S68520I4 (ammonium)

Other Names:

Ammonia extract
Novel ammonia
Novel ammonia fertilizer
Captured ammonia
Anhydrous ammonia

Summary of Petitioned Use

A petition, submitted by True Organic Products Inc. to the National Organic Standards Board (NOSB) on February 14, 2020, seeks to add ammonia extract to the National List of Allowed and Prohibited Substances under Title 7 of the Code of Federal Regulations Section 205.602 (7 CFR 205.602). The petition describes ammonia extract as ammonia (NH₃) and/or ammonium (NH₄⁺) compounds captured, extracted, and/or concentrated from chemical, environmental, or biological processes (USDA 2020). This petition seeks to prohibit the use of ammonia and ammonium compounds, whether they are formed through synthetic or non-synthetic methods.

Most commercially available ammonia and ammonium compounds are formed through the synthetic Haber-Bosch process, making ammonia fertilizers and other agricultural products prohibited from use in organic agriculture, unless specifically allowed under 7 CFR 205.601. Though new production methods have been developed for the production and/or isolation of ammonia and ammonium compounds from environmental and biological sources, the petition seeks to prohibit the use of these potential non-synthetic ammonia and ammonium sources along with the already prohibited synthetic sources.

Characterization of Petitioned Substance

Composition of the Substance:

According to the definition of ammonia extract by the petitioners, it is "a fertilizer produced using a range of methods where the output contains ammonia (NH₃) and/or ammonium (NH₄⁺) that has been: 1) produced through a biological or physical process; 2) captured in a liquid form; 3) concentrated and/or extracted; and 4) packaged for application in a crop system" (USDA 2020). This definition essentially classifies all ammonia and ammonium compounds produced by non-chemical methods (e.g., the Haber-Bosch process) as ammonia extract. However, it may be helpful to state this explicitly, and then elaborate to the points expressed in the petitioner's definition for clarity. Consider, for example, the following:

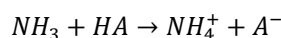
Ammonia extract is defined as fertilizers and other substances that contain ammonia (NH₃) and compounds including ammonium ions (NH₄⁺) that are produced through non-chemical methods (including, but not limited to the Haber-Bosch process and electrochemical production). This includes ammonia

54 *and ammonium ions and compounds that have been: 1) produced through a*
 55 *biological or physical process; 2) captured in a liquid form; 3) concentrated*
 56 *and/or extracted; and 4) packaged for application in a crop system.*

57
 58 Ammonia extract is differentiated from ammonia and ammonium-based fertilizers and other substances used in
 59 conventional agriculture by their source. Ammonia extract represents all ammonia (NH₃) and ammonium (NH₄⁺)
 60 compounds that are isolated from processes other than chemical processes, mainly the Haber-Bosch process
 61 (USDA 2020). Ammonia extract is not a single compound and includes ammonia and any ammonium
 62 compounds formed during or after isolation or concentration processes. The predominant methods for the
 63 isolation of ammonia extract are discussed in greater detail in Evaluation Question 2, and include both synthetic
 64 and non-synthetic formulations, as discussed in Evaluation Question 3.

65
 66 The vast majority of ammonia and ammonium compounds are products of the Haber-Bosch process, which
 67 produces > 200 million metric tons of ammonia per year (Erisman et al. 2008, Fowler et al. 2013, Soloveichik 2019,
 68 Li et al. 2020). The Haber-Bosch process produces ammonia by combining nitrogen (N₂) and hydrogen (H₂) gases
 69 in the presence of an iron catalyst (Soloveichik 2019, Li et al. 2020). This process uses nitrogen from the
 70 atmosphere and hydrogen is generally isolated from natural gas or coal feedstocks (Soloveichik 2019, Li et al.
 71 2020). Additionally, the Haber-Bosch process occurs under high pressures (100-200 bar) and high temperatures
 72 (400-500 °C) which makes ammonia production an energy intensive process (Li et al. 2020).

73
 74 Ammonia is a gas under standard conditions, although it can be concentrated into a liquid form, and its high
 75 water solubility allows for the preparation of aqueous solutions (PC 2004a, Airgas 2019). Ammonium (NH₄⁺) is a
 76 positively charged ion derived from ammonia when ammonia is reacted with an acid (HA), as shown below in
 77 Equation 1 (Silberberg 2003, Shriver and Atkins 2008). However, ammonium does not exist on its own and will
 78 always be present with a negatively charged counter ion (shown as A⁻ in Equation 1), the identity of which is
 79 based on the acid reacted with ammonia to produce the ionic ammonium compound (Silberberg 2003, Shriver
 80 and Atkins 2008, Folino et al. 2020).



81
 82
 83
 84 **Equation 1.**

85
 86 *Isotopic differences between synthetic ammonia and ammonia extract*

87
 88 Ammonia and ammonium, which fall under the umbrella of ammonia extract, have been reported to be different
 89 from chemical sources of ammonia and ammonium produced through the Haber-Bosch process (Bateman and
 90 Kelly 2007, Mukome et al. 2013, Chung et al. 2017, Francois et al. 2020). Synthetic, chemically derived ammonia is
 91 produced through the Haber-Bosch process and exists with an isotopic ratio of ¹⁵N/¹⁴N—approximately the same
 92 as found in nature (e.g., atmospheric dinitrogen [N₂], relative abundance 0.368% ¹⁵N) (Bateman and Kelly 2007).
 93 However, the ¹⁵N/¹⁴N ratio found in ammonia extract has been reported to be enriched in the heavier ¹⁵N isotope
 94 (Bateman and Kelly 2007, Mukome et al. 2013, Chung et al. 2017, Francois et al. 2020).

95
 96 The relative enhancement of ¹⁵N in relation to the natural isotopic abundance of ¹⁵N is described in the literature
 97 in δ-notation units (per mil [‰]), according to Equation 2 below (Bateman and Kelly 2007). The ¹⁵N/¹⁴N (standard) term
 98 in Equation 2 is based on the natural isotopic abundance of ¹⁵N and is equal to 0.00368 (Bateman and Kelly 2007).
 99 According to Equation 2, substances that have no enrichment of either stable nitrogen isotope (¹⁵N or ¹⁴N) would
 100 have a δ¹⁵N of 0‰.

$$\delta^{15}N_{sample}(\text{‰}) = \frac{\frac{^{15}N}{^{14}N} (sample) - \frac{^{15}N}{^{14}N} (standard)}{\frac{^{15}N}{^{14}N} (standard)} \times 1000$$

101
 102
 103
 104 **Equation 2.**

105

106 The increase in $\delta^{15}\text{N}$ differs based on the source and treatment of ammonia extract and has been reported to
107 range from a 1–37% increase compared to synthetic ammonia and ammonium compounds (Bateman and Kelly
108 2007, Mukome et al. 2013, Chung et al. 2017). Most sources of ammonia extract and organic sources of ammonia
109 and ammonium compounds have $\delta^{15}\text{N} > 5\%$, while synthetic ammonia and ammonium compounds generally
110 have $\delta^{15}\text{N} < 4\%$, (Bateman and Kelly 2007, Mukome et al. 2013, Chung et al. 2017, Francois et al. 2020).

111
112 Ionic compounds typically exist as solids with high boiling points (Silberberg 2003, Shriver and Atkins 2008).
113 However, ammonium compounds can act as acids to produce ammonia, which exists as a gas under standard
114 conditions (Silberberg 2003, Timberlake 2016). The conversion of ammonium ions to ammonia, which is readily
115 evaporated to a gas, is known as ammonium volatilization and is shown below in Equation 3.



Equation 3.

121 The enhancement of ^{15}N in relation to natural isotopic abundance is due to the kinetic (reaction rate)
122 phenomenon known as the kinetic isotope effect (KIE). KIEs are observed when bonds are broken or formed,
123 with lighter isotopes producing faster rates than heavier isotopes due to frequency differences of the respective
124 molecular vibrations (Shriver and Atkins 2008). The faster rate of conversion of ammonium compounds with ^{14}N
125 results in the preferential volatilization and removal of ^{14}N and results in enhancement of ^{15}N in the remaining
126 compounds (Bateman and Kelly 2007, Chung et al. 2017).

Source or Origin of the Substance:

129 Ammonia extract is ammonia that is from sources other than the Haber-Bosch process. Ammonia extract can be
130 derived from many sources including chemical, environmental, or biological processes, and includes both
131 ammonia and ammonium compounds formed during isolation processes (USDA 2020). These processes include
132 isolation of ammonia and ammonium compounds that are produced through anaerobic digestion and
133 fermentation processes, as well as the capture/extraction from environmental and chemical sources (e.g.,
134 isolation from biogas, isolation from chemical flue gases) (Latvala et al. 2013, Kinidi et al. 2018, Folino et al. 2020,
135 Jakobsson et al. 2020, Lorick et al. 2020, USDA 2020). These processes are discussed in greater detail in Evaluation
136 Questions 2 and 3.

Properties of the Substance:

139 “Ammonia extract” is a term that applies to ammonia and many possible ammonia compounds. Ammonia
140 is an inorganic compound that exists as a gas at room temperature (Silberberg 2003, PC 2004a, Timberlake
141 2016, Airgas 2019). The lone pair of electrons held by the nitrogen atom results in the compound being
142 weakly basic and capable of accepting a proton (H^+) from an acid, as shown in Equation 1. The properties
143 of the ammonia and ammonium ions that make up the ammonia extract are listed below in Table 1.

144
145 Ammonium is a positively charged ion and represents only a portion of the overall ionic compound in
146 which it exists. Ammonium ions are generally produced as the conjugate acid when ammonia reacts with
147 an acid, as shown in Equation 1 (Silberberg 2003, Timberlake 2016). In the acid-base production of
148 ammonium ions, the remainder of the ionic compound is dictated by the anion provided by the initial acid
149 (A^- in Equation 1) (Silberberg 2003, Timberlake 2016). Since the negative ion paired with ammonium is
150 unknown in the general description of ammonia extract, discussion will be focused on the positive
151 ammonium ion.

152
153 Ammonium is present as a positive ion in many possible ionic compounds. These compounds are
154 generally present as solids under standard conditions, and typically have high water solubility (Silberberg
155 2003, Timberlake 2016). The ammonium ion is also a weak acid, which can donate a proton to a base to
156 regenerate ammonia, as shown in Equation 3 (Silberberg 2003).

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Table 1. Properties of ammonia extract

Compound	Ammonia (NH ₃)	Ammonium (NH ₄ ⁺)
CAS Number	7664-41-7	14798-03-9
Molecular Weight	17.03 g/mole	18.04 g/mole
General Appearance	Colorless gas or compressed liquid	Dependent on anion. Generally exists as a solid
Odor	Sharp, pungent, repelling	N/A
Solubility	540 g/L in water, also soluble in alcohols and ethers	Dependent on anion. Generally soluble in water and alcohols
Melting Point	-77.7 °C, -107.9 °F	Dependent on anion
Boiling Point	-33 °C, -27.4 °F	Dependent on anion
Density	0.59 (relative to air as 1)	Dependent on anion
Vapor Pressure	114.1 psig	Dependent on anion
pH	11.6	4.5-6.0

Sources: PC 2004a, PC2004b, Airgas 2019, ThermoFisher 2019

Specific Uses of the Substance:

Ammonia extract, like synthetic ammonia sources, is most often used in the production of nitrogen fertilizers (EPA 1995, Erisman et al. 2008, Fowler et al. 2013, Li et al. 2020, USDA 2020). Most commercial nitrogen fertilizers are not currently allowed in organic agriculture since most ammonia is manufactured via the Haber-Bosch process; they are designated as synthetic inputs (EPA 1995, Erisman et al. 2008, Fowler et al. 2013, Li et al. 2020).

Nitrogen fertilizers are common in conventional agriculture production as a source of the macro nutrient nitrogen (Spiertz 2009, Anas et al. 2020). Urea is the most common form of nitrogen in nitrogen fertilizers, accounting for approximately 50%; however, other substances are also common, including aqueous ammonia, ammonium nitrate, ammonium sulfate, ammonium phosphates, and other ammonium salts (EPA 1995, Latvala et al. 2013, Dari et al. 2019). These compounds provide bioavailable sources of nitrogen for crop uptake, which generally occurs through ammonium and nitrate ions (Masclaux-Daubresse et al. 2010, Bindraban et al. 2014, Hajari et al. 2015, Anas et al. 2020). The increased availability of nitrogen due to these fertilizer compounds are attributed to increased crop yields, which have been reported to increase by 2 to 3 times (Erisman et al. 2008, Spiertz 2009).

Approved Legal Uses of the Substance:

Ammonia extract is not listed as a regulated substance in the CFR. However, ammonia extract is chemically identical to synthetic ammonia and ammonium compounds, which are discussed below.

The United States Department of Agriculture (USDA) National Organic Program (NOP) allows the following uses:

- Ammonium soaps in organic agricultural production “for use as a large animal repellent only, no contact with soil or edible portion of crop” (7 CFR 205.601).
- Ammonium carbonate in organic agricultural production “for use as bait in insect traps only, no direct contact with crop or soil” (7 CFR 205.601).
- Ammonium bicarbonate and ammonium carbonate in organic agricultural production “for use only as a leavening agent” (7 CFR 205.605).

The United States Food and Drug Administration (FDA) allows the following uses:

- Ammonia to produce ammonium formate for manufacture of swine feeds by “the reaction of 99.5 percent ammonia gas and 99 percent formic acid in a continuous loop reactor to produce a solution made up of 37 percent ammonium salt of formic acid and 62 percent formic acid” (21 CFR 573.170).
- Ammonia in the production of the food additive diammonium phosphate “resulting from the neutralization of feeding-phosphoric-acid of defluorinated wet-process phosphoric acid with anhydrous ammonia,” for use in ruminant feeds (21 CFR 573.320).

- 202 • Ammonia in the production of the food additive fermented ammoniated condensed whey, which
203 is “produced by the *Lactobacillus bulgaricus* fermentation of whey with the addition of ammonia”
204 (21 CFR 573.450).
- 205 • Ammonia for reaction with “fatty triglycerides, marine oils, and the fatty acids and alcohols
206 derived therefrom,” to produce “defoaming agents used in the manufacture of paper and
207 paperboard” (21 CFR 176.210).
- 208 • Ammonium salts of volatile fatty acids with the stipulation that these salts are composed of “48 to
209 54 percent of ammonium salts of mixed 5-carbon acids, 22 to 26 percent of ammonium salt of
210 isobutyric acid, and a 28 percent maximum of water and 0.3 percent maximum of ammonia” (21
211 CFR 573.914).
- 212 • Ammonium salts of “fatty acids from vegetable or animal oils” (21 CFR 175.320).
- 213 • The ammonium salt of butanedioic acid, sulfo-1,4-di(C₉-C₁₁ alkyl)ester “for use as a surface active
214 agent” (21 CFR 178.2400).
- 215 • Ammonium persulfate, ammonium thiosulfate, the ammonium salt of castor oil, the ammonium
216 salts of fatty acids derived from animal and vegetable fats and oils, ferrous ammonium sulfate,
217 ammonium salts of lauryl sulfate, ammonium salts of sulfated mustardseed oil, ammonium
218 sulfated oleic acid salts, ammonium salts of sulfated rapeseed oil, ammonium salts of sulfated
219 ricebran oil, the ammonium salt of sulfated sperm oil, the ammonium salt of sulfated tallow, the
220 ammonium salt of sulfated butyl oleate, the ammonium salts of ethylene-acrylic acid copolymers,
221 and the ammonium salt of sulfated isobutyl oleate as “components of paper and paperboard in
222 contact with aqueous and fatty foods,” without limitations (21 CFR 176.170).
- 223

224 **The FDA has designated several ammonium compounds as Generally Recognized as Safe (GRAS) in 21**
225 **CFR Parts 182, 184, and 582:**

- 226 • Ammonium alum salts (double sulfate of aluminum and ammonium) as a GRAS “substance
227 migrating to food from paper and paperboard products used in food packaging” (21 CFR 182.90).
- 228 • Aluminum ammonium sulfate as GRAS “when used in accordance with good manufacturing
229 practice” (21 CFR 182.1127 and 21 CFR 582.1127).
- 230 • Monoammonium glutamate as GRAS “when used in accordance with good manufacturing
231 practice” (21 CFR 182.1500 and 21 CFR 582.1500).
- 232 • Ammonium bicarbonate, ammonium carbonate, ammonium hydroxide, ammonium phosphate
233 (mono- and dibasic), ammonium sulfate, and ammonium alginate as GRAS “when used in
234 accordance with good manufacturing practice” (21 CFR 582.1135, 21 CFR 582.1137, 21 CFR
235 582.1139, 21 CFR 582.1141, 21 CFR 582.1143, and 21 CFR 582.7133, respectively).
- 236 • Ammonium alginate has received GRAS status for uses as a thickener and stabilizer with a
237 maximum level of use set as “0.4 percent for confections and frostings, 0.5 percent for fats and oils,
238 0.5 percent for gelatins and puddings, 0.4 percent for gravies and sauces, 0.4 percent for jams and
239 jellies, 0.5 percent for sweet sauces, and 0.1 percent for all other foods” (21 CFR 184.1133).
- 240 • Ammonium bicarbonate as GRAS when “prepared by reacting gaseous carbon dioxide with
241 aqueous ammonia” (21 CFR 184.1135). Ammonium bicarbonate may be “used in food with no
242 limitation other than good manufacturing practice,” and is commonly used as a dough softener,
243 leavening agent, pH control agent, and texturizer, as described in §184.1135.
- 244 • Ammonium carbonate as GRAS when “prepared by the sublimation of a mixture of ammonium
245 sulfate and calcium carbonate” (21 CFR 184.1137). The FDA has designated that ammonium
246 carbonate may be “used in food with no limitation other than good manufacturing practice,” and is
247 commonly used as a leavening agent and pH control agent, as described in §184.1137.
- 248 • Ammonium chloride as GRAS when “produced by the reaction of sodium chloride and an
249 ammonium salt in solution. The less soluble sodium salt precipitates out at elevated temperatures,
250 and ammonium chloride is recovered from the filtrate on cooling. Alternatively, hydrogen chloride
251 formed by the burning of hydrogen in chlorine dissolved in water and then reacted with gaseous
252 ammonia. Ammonium chloride is crystallized from solution” (21 CFR 184.1138). Ammonium
253 chloride may be “used in food with no limitation other than good manufacturing practice,” and is
254 commonly used as a dough strengthener, flavor enhancer, leavening agent and processing aid, as
255 described in §184.1138.

- 256 • Ammonium hydroxide as GRAS when “produced by passing ammonia gas into water” (21 CFR
257 184.1139). The FDA has designated that ammonium hydroxide may be “used in food with no
258 limitation other than good manufacturing practice,” and is commonly used as a leavening agent,
259 pH control agent, surface-finishing agent, and boiler water additive, as described in §184.1139.
- 260 • Ammonium citrate as GRAS when “prepared by partially neutralizing citric acid with ammonia”
261 (21 CFR 184.1140). The FDA has designated that ammonium citrate may be “used in food with no
262 limitation other than good manufacturing practice,” and is commonly used as a flavor enhancer
263 and pH control agent, and is used in nonalcoholic beverages and cheeses, as described in
264 §184.1140.
- 265 • Ammonium phosphate, monobasic as GRAS when “manufactured by reacting ammonia with
266 phosphoric acid at a pH below 5.8” (21 CFR 184.1141a). The FDA has designated that ammonium
267 phosphate, monobasic may be “used in food with no limitation other than good manufacturing
268 practice,” and is commonly used as a dough strengthener and pH control agent, as described in
269 §184.1141a.
- 270 • Ammonium phosphate, dibasic as GRAS when “manufactured by reacting ammonia with
271 phosphoric acid at a pH higher than 5.8” (21 CFR 184.1141b). The FDA has designated that
272 ammonium phosphate, dibasic may be “used in food with no limitation other than good
273 manufacturing practice,” and is commonly used as a dough strengthener, firming agent, leavening
274 agent, pH control agent, and processing aid, as described in §184.1141b.
- 275 • Ammonium sulfate as GRAS when “prepared by the neutralization of sulfuric acid with
276 ammonium hydroxide” (21 CFR 184.1143). Ammonium sulfate has received GRAS status as a
277 dough softener, firming agent, and processing agent with “a maximum level, as served, of 0.15
278 percent in baked goods, and 0.1 percent in gelatins and puddings,” as described in §184.1143.
- 279 • Ferric ammonium citrate as GRAS when “prepared by the reaction of ferric hydroxide with citric
280 acid, followed with ammonium hydroxide, evaporating and drying” (21 CFR 184.1296). The FDA
281 has designated that ferric ammonium citrate may be “used in food with no limitation other than
282 good manufacturing practice,” and is commonly used in nutrient supplements and infant formula,
283 as described in §184.1296.
- 284 • Ammoniated glycyrrhizin as licorice and licorice derivatives as GRAS when “prepared from the
285 water extract of licorice root by acid precipitation followed by neutralization with dilute ammonia”
286 (21 CFR 184.1408). The FDA has designated ammoniated glycyrrhizin as a GRAS component of
287 essential oils (21 CFR 582.20).
- 288 • Ammonium citrate as a GRAS “substance added to animal feeds as a nutritional dietary
289 supplement when added at levels consistent with good feeding practice” (21 CFR 582.80).

290
291 **The EPA lists the following:**

- 292 • Glufosinate ammonium, ammonium bicarbonate, and ammonium salts of higher fatty acids
293 (soaps) are listed in 40 CFR 180. Glufosinate ammonium has many tolerances for residues for a
294 variety of foodstuffs ranging from 0.05 to 25 ppm, as stipulated in §180.473. Ammonium
295 bicarbonate and ammonium salts of higher fatty acids are exempt from the requirement of a
296 tolerance (40 CFR 180.1244 and 40 CFR 180.1284, respectively).
- 297 • Diammonium ethylenebis(dithiocarbamate), ammonium(4-(p(dimethylamino)-alpha-
298 phenylbenzylidene)-2,5-cyclohexadien-1-ylidene)-dimethyl chloride, ammonium salts of C8-C18
299 and C18' fatty acids, benzyl diethyl ((2,6-xylylcarbonyl)methyl) ammonium benzoate, copper
300 ammonium carbonate, ammonium ethylenediaminetetraacetate, ammonium 1-naphthaleneacetate,
301 ammonium 2-phenylphenate, ammonium fluosilicate, ammonium thiosulfate, ammonium alum,
302 fosamine ammonium, monoammonium imazaquin, and the ammonium salt of imazethapyr as
303 “organic pesticide active ingredients” (40 CFR 455.67).
- 304 • Ammonia and ammonium salts of acetate, benzoate, bicarbonate, bichromate, bifluoride, bisulfite,
305 carbamate, carbonate, chloride, chromate, citrate dibasic, fluoroborate, fluoride, hydroxide,
306 oxalate, silicofluoride, sulfamate, sulfide, sulfite, tartrate, and thiocyanate as hazardous substances
307 (40 CFR 116.4). Additionally, the EPA also lists ammoniated cupric sulfate, ferric ammonium
308 citrate, ferric ammonium oxalate, ferrous ammonium sulfate, nickel ammonium sulfate, and zinc
309 ammonium chloride as hazardous substances, as described in §116.4.

- 310 • A 1 µg/liter maximum concentration of “un-ionized ammonia” in surface and ground water (40
311 CFR 797.1330).

312

Action of the Substance:

314 Ammonia extract, and the nitrogen fertilizers that can be produced by processing the substance, act as a
315 macro nutrient and bioavailable source of nitrogen (Erisman et al. 2008, Spiertz 2009, Fowler et al. 2013,
316 Bindraban et al. 2014, Anas et al. 2020). Nitrogen is an important component of many organic and
317 biologically important compounds including amino acids (Howrath 2008, Fowler et al. 2013). The presence
318 of nitrogen is important for plant growth through the formation of amino acids as the building blocks for
319 proteins and has also been reported to improve the efficiency of photosynthesis (Dreccer et al. 2000,
320 Cabrera-Bosquet 2007, Howrath 2008, Spiertz 2009, Anas et al. 2020).

321

322 Ammonia and ammonium compounds in nitrogen fertilizers provide water soluble and bioavailable
323 nitrogen compounds. Nitrogen uptake by plants has been shown to predominantly be through ionic
324 sources that are able to be transported through root membranes (Masclaux-Daubresse et al. 2010,
325 Bindraban et al. 2014, Hajari et al. 2015, Anas et al. 2020). Studies have shown that ammonium and nitrate
326 are most efficiently absorbed by plants, and that between the two ions, nitrate typically has greater
327 mobility (Bindraban et al. 2014). Ammonium ions are often converted to nitrate ions in the root systems of
328 plants by enzymatic oxidation processes to produce the more mobile nitrate ion, through which nitrogen is
329 efficiently distributed through the xylem (Spiertz 2009, Bindraban et al. 2014).

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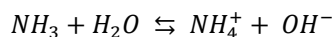
Combinations of the Substance:

332 75–80% of synthetic ammonia derived from the Haber-Bosch process is used for the production of nitrogen
333 fertilizers (EPA 1995, Erisman et al. 2008, Fowler et al. 2013, Li et al. 2020). Ammonia extract is a substance
334 that offers an alternative feedstock for the production of nitrogen fertilizers and would likely be
335 transformed into common forms of fertilizer. The most common forms of nitrogen fertilizers in
336 conventional agriculture are aqueous ammonia, urea, ammonium nitrate, ammonium sulfate, ammonium
337 phosphates, and other ammonium salts (EPA 1995, Latvala et al. 2013, Dari et al. 2019).

338

339 In the production of aqueous ammonia, which is sometimes referred to as liquid ammonia in the literature,
340 ammonia is dissolved in water. The basic nature of ammonia and the amphiprotic nature of water results
341 in the formation of a secondary reaction in solution, where water acts as an acid and donates a proton to
342 the basic ammonia to generate small portions of ammonium hydroxide, as shown below in Equation 4
343 (Silberberg 2003). The reversible nature of this reaction lies heavily to the reactant side, with only a small
344 portion of aqueous ammonia being converted to ammonium hydroxide (Silberberg 2003).

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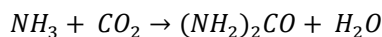
Equation 4.

348

349

350 Urea is the most common component of nitrogen fertilizers and in natural wastes applied as fertilizers, and
351 accounts for approximately 50% of nitrogen fertilizers (Dari et al. 2019). In the production of urea,
352 ammonia is combined with carbon dioxide to generate urea and water, as shown below in Equation 5
353 (Timberlake 2016).

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355

356

Equation 5.

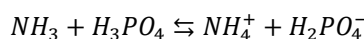
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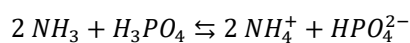
359 The production of ammonium nitrate, ammonium sulfate, ammonium phosphates, and other ammonium
360 salts that are common in nitrogen fertilizers all follow the same general reaction, where ammonia is
361 neutralized with an acid, as shown previously in Equation 1 (Silberberg 2003, Shriver and Atkins 2008,
362 Folino et al. 2020). The identity of the ammonium salt produced is dependent on the acid, with the
363 remaining, negatively charged portion of the acid making up the A⁻ component shown in Equation 1.
364 Through this general reaction, ammonium nitrate (NH₄NO₃) is produced by neutralizing ammonia with

365 the strong acid nitric acid (HNO₃), ammonium sulfate ((NH₄)₂SO₄) is produced by neutralizing ammonia
 366 with the strong acid sulfuric acid (H₂SO₄), and many other ammonium salts may be produced through the
 367 neutralization of ammonia with various acids (Silberberg 2003, Shriver and Atkins 2008, Folino et al. 2020).

368
 369 Phosphoric acid (H₃PO₄) is different from the previously discussed acids, since it is both a weak acid (does
 370 not completely ionize in water) and polyprotic (capable of donating multiple protons to a base) (Silberberg
 371 2003, Shriver and Atkins 2008, Timberlake 2016). These characteristics produce two main forms of
 372 ammonium phosphate, monobasic (NH₄H₂PO₄) in which the initial phosphoric acid neutralizes one
 373 molecule of ammonia, as shown in Equation 6, or the dibasic form ((NH₄)₂HPO₄) in which the initial
 374 phosphoric acid neutralizes two molecules of ammonia, as shown below in Equation 7. The degree of
 375 neutralization is based on the amount of free acid present (H⁺), which is described in the pH of the
 376 solution. When ammonia is neutralized in a solution of phosphoric acid with a pH above 5.8, Equation 6 is
 377 dominant and monobasic ammonium phosphate is generated. When the solution is more acidic, with a pH
 378 below 5.8, Equation 7 is dominant and dibasic ammonium phosphate is produced (Silberberg 2003).



381
 382 **Equation 6.**



385
 386 **Equation 7.**

387
 388 When ammonia extract is produced via ammonia concentration processes, the resulting liquid nitrogen
 389 fertilizer product may include other water soluble salts and compounds. The identity of these compounds
 390 is dependent on the source of the organic feedstock, and may include phosphate, potash, secondary and
 391 micronutrients, and other organic compounds (Bisson et al. 2013). The ammonia concentration process is
 392 discussed in greater detail in Evaluation Question 2.

394 Status

395 **Historic Use:**

396 Ammonia extract, and ammonia and ammonium compounds more generally, have little historic use in
 397 organic agriculture. USDA NOP has approved the use of the synthetic compounds ammonium soaps and
 398 ammonium carbonate as repellent for large animals and bait for insect traps, but expressly prohibits their
 399 application to soils and edible portions of crops in 7 CFR 205.601.

400
 401
 402 Ammonia and ammonium compounds are important components and precursors to compounds that are
 403 found in nitrogen fertilizers. Approximately 75–80% of synthetic ammonia is used to produce these
 404 fertilizers, which are prominently used in conventional agriculture (Erisman et al. 2008, Fowler et al. 2013,
 405 Anas et al. 2020, Li et al. 2020). Nitrogen fertilizers provide water soluble and bioavailable sources of
 406 nitrogen macro nutrients and are widely credited for the dramatic improvement in the efficiency and crop
 407 yields since their introduction over 100 years ago (Erisman et al. 2008, Anas et al. 2020).

408 **Organic Foods Production Act, USDA Final Rule:**

409 Ammonia extract is not listed in the Organic Foods Production Act of 1990 (OFPA). Ammonia extract is not
 410 listed in the USDA organic regulations in 7 CFR 205. Ammonia is generally produced through the
 411 Haber-Bosch process, making it a synthetic substance that is not permitted for use in organic agriculture.

412
 413
 414 Ammonia extract may include sources of ammonia and ammonium that may be considered non-synthetic
 415 under NOP guidelines. There are several ammonium compounds that are included in USDA organic
 416 agriculture regulations in 7 CFR 205. Ammonium soaps and ammonium carbonate are listed as “synthetic
 417 substances allowed for use in organic crop production,” in §205.601. Ammonium soaps have been
 418 approved as animal repellents “for use as a large animal repellent only, no contact with soil or edible
 419 portion of crop.” Ammonium carbonate is allowed “for use as a bait in insect traps only, no direct contact

420 with crop or soil." Ammonium bicarbonate and ammonium carbonate are listed as "nonagricultural
421 (nonorganic) substances allowed as ingredients in or on processed products labeled as 'organic' or 'made
422 with organic (specified ingredients or food group(s)),'" with the specification "for use as a leavening agent
423 only," in §205.605.

424

425 **International**

426

427 **Canada, Canadian General Standards Board Permitted Substances List (CAN/CGSB-32.311-2015),** 428 **Organic Production Systems Permitted Substances List**

429

430 Ammonia extract is not listed in the Canadian Standards Board Permitted Substances List (CAN/CGSB-
431 32.311-2015); however, it does include a variety of ammonium compounds. Copper ammonia base, copper
432 ammonium carbonate, ammonium forms of micronutrients, potassium sulfate made with ammonia
433 reactants, and ammonium stillage are prohibited for "soil amendments and crop nutrition" uses.
434 Ammonium carbonate is allowed "as an attractant in insect traps." Ammonium soaps are allowed "as a
435 large animal repellent," with the stipulation that "direct contact with soil or edible portion of crop is
436 prohibited." Ammonium lignosulphate is prohibited for "crop production aids and materials."
437 Ammonium bicarbonate and ammonium carbonate are allowed "as leavening agent[s]." Dibasic
438 ammonium phosphate (diammonium phosphate, DAP) is allowed as a "yeast food for use in alcoholic
439 beverages," with the limitation that concentrations are "restricted to 0.3 g/L (0.04 oz./gal.) for cider, mead
440 and wine."

441

442 **CODEX Alimentarius Commission, Guidelines for the Production, Processing, Labelling and Marketing** 443 **of Organically Produced Foods (GL 32-1999)**

444 Ammonia extract is not listed in the CODEX; however, ammonium carbonates are listed in the CODEX as a
445 "food additive."

446

447 **European Economic Community (EEC) Council Regulation, EC No. 834/2007 and 889/2008**

448 Ammonia extract is not listed in the EEC Council Regulation EC No. 834/2007 and 889/2008. However,
449 several ammonium compounds are listed in EC No. 889/2008. Ammonium stillage is prohibited for use as
450 a "fertiliser and soil conditioner." Diammonium phosphate is allowed as an "attractant" for traps in
451 "pesticides and plant protection products." Ammonium molybdate is allowed as a nutritional "trace
452 element" in animal feeds. Ammonium carbonates are allowed for the "preparation of foodstuffs of plant
453 origin." Ammonium hydroxide is allowed for the "preparation of foodstuffs of animal origin" in gelatine
454 production.

455

456 **Japan Agricultural Standard (JAS) for Organic Production**

457 Ammonia extract is not listed in the JAS for Organic Production. However, ammonium bicarbonate and
458 ammonium carbonate are listed in Notification No. 1606 and allowed for use as "food additives, limited to
459 use for processed foods of plant origin."

460

461 **International Federation of Organic Agriculture Movements (IFOAM)**

462 Ammonia extract is not listed in the IFOAM; however, it does list several ammonium compounds.
463 Ammonium phosphate is allowed as an "additive," with the stipulation that concentrations are "restricted
464 to 0.3gm/l in wine." Ammonium sulfate is allowed as an "additive," with the stipulation that it is only
465 allowed for wine and is "restricted to 0.3 mg/l." Ammonium carbonates are allowed as "additives," with
466 uses limited to "cereal products, confectionary, cakes and biscuits."

467

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Evaluation Questions for Substances to Be Used in Organic Crop or Livestock Production

Evaluation Question #1: Indicate which category in OFPA that the substance falls under: (A) Does the substance contain an active ingredient in any of the following categories: 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? (B) Is the substance a synthetic inert ingredient that is not classified by the EPA as inerts of toxicological concern (i.e., EPA List 4 inerts) (7 U.S.C. § 6517(c)(1)(B)(ii))? Is the synthetic substance an inert ingredient which is not on EPA List 4, but is exempt from a requirement of a tolerance, per 40 CFR part 180?

A) Ammonia extract does not contain an active ingredient of the categories listed above.

B) Ammonia extract is not listed by the EPA as an inert of toxicological concern. Ammonia extract is not included on EPA List 4. There are many ammonium compounds that are included on EPA List 4, which are listed below in Table 2.

Table 2. Ammonium compounds in EPA List 4

Ammonium Compound	CAS Number
Acetic acid ammonium salt	631-61-8
Ammonium alum	7784-25-0
Ammonium bisulfate	7803-63-6
Ammonium bromide	12124-97-9
Ammonium carbamate	1111-78-0
Ammonium chloride	12125-02-9
Ammonium citrate, dibasic	3012-65-5
Ammonium diisodecyl sulfosuccinate	94313-89-0
Ammonium fluosilicate	16919-19-0
Ammonium formate	540-69-2
Ammonium hydroxide	1336-21-6
Ammonium nitrate	6484-52-2
Ammonium persulfate	7727-54-0
Ammonium phosphate, monobasic	7722-76-1
Ammonium polyphosphate	68333-79-9
Ammonium sulfate	7783-20-2
Ammonium thiocyanate	1762-95-4
Benzoic acid, ammonium salt	1863-63-4
Carbonic acid, ammonium salt	10361-29-2
Carbonic acid, monoammonium	1066-33-7
Carbonic acid, diammonium salt	506-87-6
Dodecyl sulfate, ammonium salt	2235-54-3
Dodecylbenzenesulfonic acid, ammonium salt	1331-61-9
Ferric ammonium sulfate	10138-04-2
Ferrous ammonium sulfate	10045-89-3
Lactic acid, monoammonium salt	515-98-0
Lignosulfonic acid, ammonium salt	8061-53-8
Nitric acid, ammonium calcium salt	15245-12-2
Octadecanoic acid, ammonium salt	1002-89-7
Xylenesulfonic acid, ammonium salt	26447-10-9

Additionally, glufosinate ammonium, ammonium bicarbonate, and ammonium salts of higher fatty acids (soaps) are listed in 40 CFR 180. Glufosinate ammonium has many tolerances for residues for a variety of

497 foodstuffs ranging from 0.05 to 25 ppm, as stipulated in §180.473. Ammonium bicarbonate and ammonium
498 salts of higher fatty acids are exempt from the requirement of a tolerance, as stipulated in §180.1244 and
499 §180.1284, respectively.

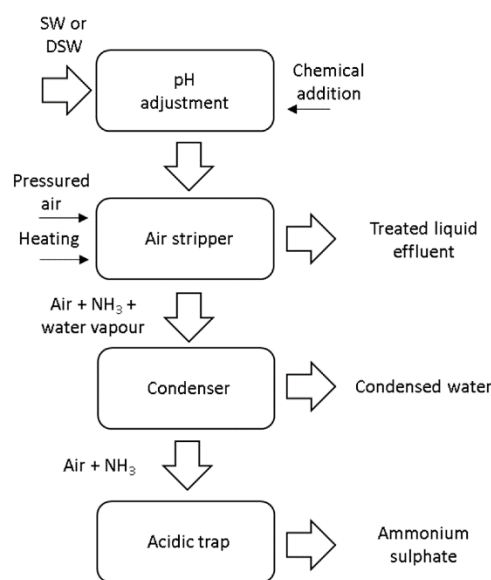
500
501 **Evaluation Question #2: Describe the most prevalent processes used to manufacture or formulate the**
502 **petitioned substance. Further, describe any chemical change that may occur during manufacture or**
503 **formulation of the petitioned substance when this substance is extracted from naturally occurring plant,**
504 **animal, or mineral sources (7 U.S.C. § 6502 (21)).**
505

506 Ammonia extract is defined as ammonia and ammonium compounds that have been isolated from
507 processes other than the Haber-Bosch process, as described above in the Composition of the Substance
508 section (USDA 2020). The major production/isolation of ammonia is the process of ammonia stripping or
509 air stripping (Wu et al. 2018, Folino et al. 2020, Lorick et al. 2020). Ammonia stripping describes the
510 isolation of ammonia and ammonium compounds from biogas, flue gases, wastewater and sewage sludge
511 treatment, and anaerobic digestion of agricultural and biological wastes (Wu et al. 2018, Jakobsson et al.
512 2019, Folino et al. 2020, Lorick et al. 2020, Chen et al. 2021). Ammonia concentration is another production
513 method of ammonia extract, which uses the same chemical and physical principles as ammonia stripping
514 processes (Bisson et al. 2013). However, at the time of this report, the ammonia-stripping and concentration
515 processes are largely in the development phase, with few large or full-scale operations (Lorick et al. 2020).
516 Given the large scale of ammonia production via the Haber-Bosch process, and the limited scale
517 production of ammonia extract, it has a nearly negligible contribution to overall global ammonia
518 production (Erisman et al. 2008, Fowler et al. 2013, Soloveichik 2019, Li et al. 2020, Lorick et al. 2020).

519
520 *Ammonia stripping*

521
522 Since ammonia stripping is currently in the developmental stage, individual set ups vary based on the
523 feedstock being processed, desired temperatures, and pH values of the various steps in the process (Kinidi
524 et al. 2018, Folino et al. 2020, Lorick et al. 2020). This section will use Scheme 1 outlined below by Folino et
525 al. to describe the most common processes in ammonia-stripping reports (Folino et al. 2020).

526



527

528

529

530

Scheme 1 (Folino et al. 2020).

531 In the first step, the treated material (listed as SW or DSW in Scheme 1) undergoes pH adjustment.
532 Ammonium compounds are prevalent in agricultural, biological, wastewater, and sewage wastes that are
533 common feedstocks of the ammonia-stripping process. Ammonium is a common end point for the
534 metabolism and hydrolysis processes that occur in the production of these feedstocks or are facilitated by

535 the pretreatment through anaerobic digestion to facilitate these metabolic processes (Latvala et al. 2013,
536 Mehta et al. 2015, Kinidi et al. 2018, Folino et al. 2020, Chen et al. 2021).

537
538 As discussed above in the Composition of the Substance section, ammonium is a portion of an ionic
539 compound, which typically have high boiling points and high water solubility (Silberberg 2003, Shriver
540 and Atkins 2008). However, ammonium ions can be converted to ammonia, which is a gas under standard
541 conditions, by treatment with a base, as described in Equation 3. This is the process that occurs in the pH
542 adjustment phase, as the conversion results in increased pH to alkaline conditions. The final pH following
543 the adjustment varies between 8 and 12.9, although most processes report a pH between 9 and 10 (Folino et
544 al. 2020, Lorick et al. 2020). The pH adjustment and conversion of ammonium to ammonia is accomplished
545 through the addition of a chemical base, as signified by the “chemical addition” arrow at the initial pH
546 adjustment step in Scheme 1 (Folino et al. 2020, Lorick et al. 2020). This chemical addition can be any basic
547 compound, although lime, caustic soda, and calcium hydroxide were the most common substances
548 reported (Sengupta et al. 2015, Kinidi et al. 2018, Folino et al. 2020).

549
550 Once the feedstock has been brought to an alkaline pH and ammonium ions have been converted to
551 ammonia, the next step is to isolate the ammonia from the rest of the treated material. In this step, a
552 combination of pressured air and/or heating facilitate the extraction of ammonia in the gas phase (Folino et
553 al. 2020). Since ammonia exists as a gas under standard temperatures, its solubility is inversely dependent
554 on temperature, as stipulated by Henry’s Law (Silberberg 2003). The temperatures used in this step vary,
555 but generally operate in the range of 30–80 °C (Folino et al. 2020). Increasing the temperature decreases the
556 solubility of the ammonia and helps facilitate its diffusion into the gas phase (Kinidi et al. 2018, Folino et al.
557 2020, Lorick et al. 2020). Following the isolation from the remainder of the feedstock, the material is
558 isolated for further processing (Folino et al. 2020).

559
560 The pressured air has a two-fold effect on this isolation procedure. The airflow prevents the buildup of
561 ammonia concentration in the gas phase, which would slow the diffusion of the dissolved ammonia to the
562 gas phase for isolation (Silberberg 2003). Additionally, the incorporation of air pressure through the
563 feedstock creates air bubbles throughout the treated liquid (Kinidi et al. 2018, Folino et al. 2020). The air
564 bubbles increase the heterogeneity of the mixture and facilitate the isolation of gaseous ammonia within
565 the air pockets, and the agitation of the air bubbles disturbs the mixture to improve ammonia diffusion
566 (Kinidi et al. 2018, Folino et al. 2020). The air flow used in the isolation step varies but is commonly
567 between 0.5–10 L/min (Folino et al. 2020).

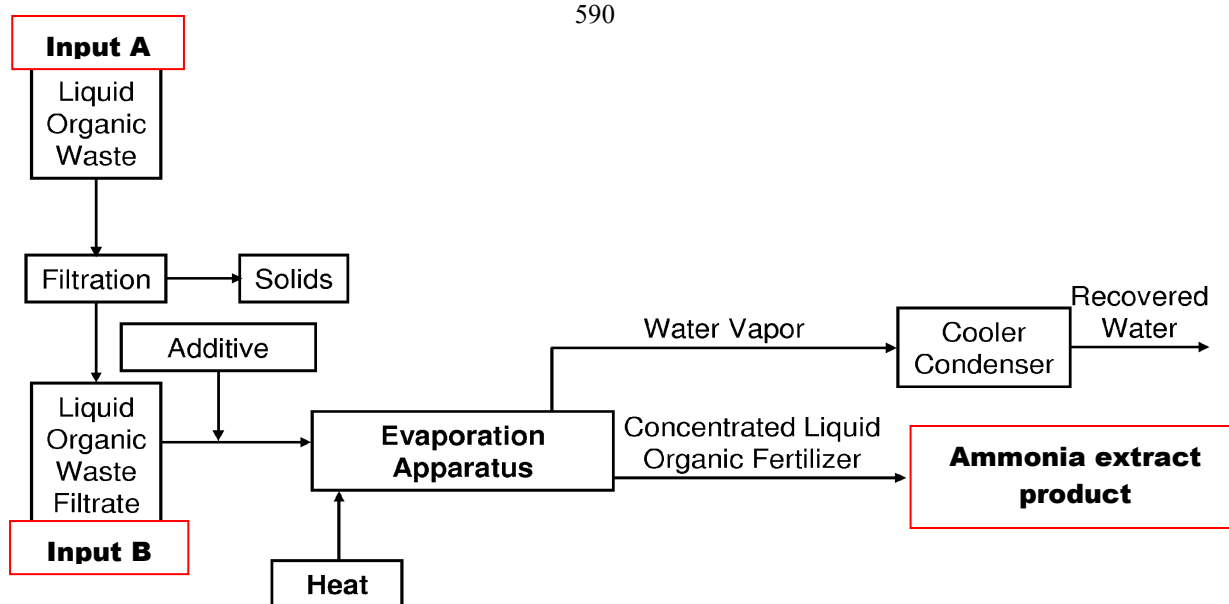
568
569 The ammonia isolation also results in the evaporation and collection of water. The degree of evaporation
570 and collection of water vapor is dependent on the temperature and rate of air flow used during the
571 isolation step. In the condensation step, ammonia is separated from water based on differences in their
572 boiling points (water = 100 °C, ammonia = -33 °C), allowing for the preferential condensation leaving
573 ammonia in the gas phase (Silberberg 2003, PC 2004a, Airgas 2019, Folino et al. 2020).

574
575 In the final stage, ammonia is reacted with an acid to form an ionic ammonium compound (Kinidi et al.
576 2018, Folino et al. 2020, Lorick et al. 2020). The reaction with an acid stabilizes the nitrogen source,
577 dramatically reducing its volatility when converted into the ionic ammonium source (Folino et al. 2020).
578 The resulting ammonium compound can be isolated as an aqueous solution or slurry, or can be isolated as
579 a solid by precipitation or solvent evaporation (Folino et al. 2020). Scheme 1 shows the final output of the
580 ammonia-stripping process as ammonium sulfate since sulfuric acid is the most common acid used in the
581 final, acid-trap step. While sulfuric acid is most used for the conversion of ammonia to ammonium, other
582 acids may be used as well (Kinidi et al. 2018, Folino et al. 2020, Lorick et al. 2020).

583 584 *Ammonia concentration*

585
586 Ammonia stripping uses the same chemical and physical principles to isolate ammonia extract from other
587 substances, although the application of these principles is different than in the ammonia stripping process
588 discussed above. This section will use Scheme 2 outlined below by Bisson et al. to describe the processes in
589 ammonia concentration (Bisson et al. 2013).

590



Scheme 2 (Bisson et al. 2013).

As shown above in Scheme 2, the ammonia concentration process allows for multiple inputs, depending on the feedstock material used for the concentration process. Discussion of the process will begin with Input A, which is the furthest upstream in the process. This process begins with liquid organic waste. This waste input may be from a variety of sources, including plant and animal byproducts, rock powders, seaweed, inoculants, conditioners, dairy product waste, livestock manure, liquid manure, worm castings, peat, guano, compost, blood meal, bone meal, fish meal, crop residues, cheese waste, and wastewater from food processing applications (Bisson et al. 2013). The liquid organic waste in Input A may be entered as untreated or having been previously processed through an anaerobic digestion process (Bisson et al. 2013). Prior anaerobic digestion of the organic waste is preferable as it metabolizes large protein and amino acid structures into ammonia and ammonium salts, thereby increasing ammonia extract yield (Bisson et al. 2013, Latvala et al. 2013, Mehta et al. 2015, Kinidi et al. 2018, Folino et al. 2020, Chen et al. 2021). Bisson et al. describe anaerobically poultry manure as the preferred source of organic waste for ammonia concentration processes (Bisson et al. 2013).

The first step in processing Input A is the removal of large and insoluble components found within the liquid organic waste mixture. This process can use many possible physical separation processes to remove unwanted solids. Bisson et al. specifically discuss the use of filtering through a 500-mesh screen, membrane filters, ultrafilters, nanofilters, or the use of extraction with continuous agitation through a turbulent flow apparatus, electro-coagulation, or through reverse osmosis (Bisson et al. 2013). The specific process used to remove unwanted solids from the mixture will depend on the liquid feedstock being processed, although Bisson et al. describe reverse osmosis as the preferred means of separation (Bisson et al. 2013). The process can include one or multiple steps to separate solids from the liquid waste mixture, with the number of steps required being dependent on the liquid feedstock and the separation method.

The recovered solids may be discarded as waste products, or further processed to recover trapped ammonia and other small molecules. Further processing of the solids includes a heating step, which liberates volatile compounds, including ammonia (Bisson et al. 2013). The ammonia-rich exhaust gas from the solid heating process is cooled and added to the remaining liquid filtrate isolated in the solid separation step to improve yield of ammonia extract (Bisson et al. 2013).

After solids have been removed from initial liquid waste mixture, the remaining liquid organic waste filtrate includes only water-soluble components. The water soluble components of the filtrate solution include ammonia and ammonium compounds, as well as phosphate, potash, secondary and micronutrients, and other organic compounds (Bisson et al. 2013). Liquid organic waste filtrate is also

627 another listed as Input B in Scheme 2. The direct incorporation of liquid waste filtrate as wastewater from
628 waste treatment facilities is the preferred input described by Bisson et al., especially when the wastewater
629 derives from processes that include anaerobic digestion (Bisson et al. 2013).

630
631 The filtrate, Input B, undergoes pH adjustment in the next step. However, the pH adjustment in ammonia
632 concentration lowers the pH, rather than increasing the pH in ammonia stripping processes (Bisson et al.
633 2013, Latvala et al. 2013, Mehta et al. 2015, Kinidi et al. 2018, Folino et al. 2020, Chen et al. 2021). This
634 process is accomplished by the addition of an acid as the “additive” listed in Scheme 2. The acid additive
635 converts residual ammonia in the solution to an ammonium salt, as described in Equation 1. The specific
636 identity of the ammonium salt is based on the acid used, as well as the other ions present in the filtrate
637 solution. The final pH of the treated solution varies based on the identity and concentration of the acid
638 used, although typically the solution pH is between 3 and 7 (Bisson et al. 2013). The acid “additive” can
639 include nearly any acid, including mineral, inorganic, and organic acid sources. Bisson et al. describe the
640 preference of organic acids to adjust the solution pH to maintain the organic nature of the liquid fertilizer
641 product, specifically listing citric acid as the preferred acid (Bisson et al. 2013).

642
643 As discussed above in the Composition of the Substance section, the conversion of ammonia to ammonium
644 ions increases the boiling points and water solubility of the resulting ionic compounds (Silberberg 2003,
645 Shriver and Atkins 2008). The increased boiling points of ammonium compounds are used to isolate the
646 ammonia extract product as a nitrogen-rich liquid fertilizer from the bulk of the solvent (water). In the final
647 concentration step, the acidic solution is heated to 32–43 °C (90 – 110 °F) to facilitate water evaporation
648 while keeping all dissolved compounds in solution (Bisson et al. 2013). The heating and evaporation
649 process may occur under normal atmospheric pressure or under reduced pressure by application of a
650 vacuum to promote water evaporation (Bisson et al. 2013). Evaporated water is condensed back into the
651 liquid phase, isolating pure, potable water from the concentration step.

652
653 The ammonium and other dissolved compounds are then isolated as the “ammonia extract products” in a
654 concentrated aqueous solution that may be applied as a nitrogen-rich liquid fertilizer (Bisson et al. 2013).
655 Unlike the ammonia extract produced in the ammonia stripping process, ammonia concentration products
656 will also include various water-soluble components, which will vary based on the initial organic waste
657 feedstock. These additional, non-ammonium, components may include ammonia and ammonium
658 compounds, as well as phosphate, potash, secondary and micronutrients, and other organic compounds
659 (Bisson et al. 2013).

660
661 **Evaluation Question #3: Discuss whether the petitioned substance is formulated or manufactured by a**
662 **chemical process, or created by naturally occurring biological processes (7 U.S.C. § 6502 (21)).**

663
664 As discussed above in Evaluation Question 2, ammonia extract can be isolated from a variety of sources,
665 which can be categorized as both chemical processes and naturally occurring biological processes.
666 Examples of chemical processes are the isolation of ammonia from biogas and as treatments for flue gases,
667 whose production are due to chemical processes (Bisson et al. 2013, Wu et al. 2018, Jakobsson et al. 2019,
668 Folino et al. 2020, Lorick et al. 2020, Chen et al. 2021).

669
670 Ammonia and ammonium compounds can also be produced through naturally occurring biological
671 processes including anaerobic digestion and fermentation, which are commonly linked in treatment of
672 agricultural and biological wastes (Bisson et al. 2013, Latvala et al. 2013, Wu et al. 2018, Jakobsson et al.
673 2019, Folino et al. 2020, Lorick et al. 2020, Chen et al. 2021). A variety of microorganisms can be used for the
674 anaerobic digestion and fermentation processes that produce ammonia and ammonium, including
675 *Methanocorpusculum*, *Methanosaeta*, *Methanobacteria*, *Clostridium*, *Eubacterium*, *Fusobacterium*,
676 *Peptostreptococcus*, and *Pseudomonas* (Latvala et al. 2013, Folino et al. 2020). These microorganisms facilitate
677 the hydrolysis from amino functional groups in biological molecules, which can be reduced to ammonia or
678 ammonium ions (Wu et al. 2018, Folino et al. 2020, Lorick et al. 2020, Chen 2021).

679
680 The ammonia and ammonium compounds are isolated following metabolism and hydrolysis processes
681 through a variety of methodologies, with ammonia stripping and ammonia concentration being the most

682 common (Bisson et al. 2013, Wu et al. 2018, Folino et al. 2020, Lorick et al. 2020). While the production of
683 ammonia and ammonium compounds (ammonia extract) occurs through natural, biological processes,
684 isolation via ammonia stripping generally utilizes acid and base reactions. The classification of ammonia
685 extract as synthetic or nonsynthetic is dependent on the identity of the acids and bases used in the
686 production of ammonia extract. According to NOP decision trees, the use of synthetic substances for pH
687 adjustment or other processing would result in the classification of the ammonia extract as synthetic, while
688 the use of natural acids and bases would result in the classification of ammonia extract as nonsynthetic
689 (NOP 2016a, NOP 2016b).

690

691 **Evaluation Question #4: Describe the persistence or concentration of the petitioned substance and/or its**
692 **byproducts in the environment (7 U.S.C. § 6518 (m) (2)).**

693

694 There are no reports of ammonia extract in relation to environmental persistence. However, ammonia
695 extract is chemically identical to synthetic ammonia and ammonium compounds, which are discussed
696 below.

697

698 Ammonia, ammonium, and their byproducts have short lifetimes in the environment, typically ranging
699 from hours to days based on environmental conditions (Howrath et al. 2002, Aneja et al. 2008, Howrath
700 2008, Fowler et al. 2013). The short environmental lifetimes of ammonia, ammonium, and their by-products
701 are due to the bioavailability of nitrogen in these compounds, which are readily incorporated into amino
702 acids and other biologically important molecules (EFSA 2008, Howrath 2008, Fowler et al. 2013). The
703 exception in the byproducts of ammonia and ammonium ions is the oxidation product nitrous oxide
704 (dinitrogen oxide [N₂O]), which can persist for approximately 120 years in the atmosphere (Vitousek et al.
705 1997, Howrath 2008, Fowler et al. 2013).

706

707 When excess ammonia is present in the environment, it is likely to volatilize and move into the atmosphere
708 as a gas (Bateman and Kelly 2007, Fowler et al. 2013, Chung et al. 2017, Anas et al. 2020). When ammonia
709 moves into the atmosphere, it may return to the environment (soil or marine systems) by the migration
710 known as dry deposition (Aneja et al. 2008, Fowler et al. 2013). In the process of dry deposition
711 atmospheric ammonia diffuses from the air to the surface of land or water, where it may be metabolized by
712 various organisms or react with acids to form ammonium compounds (Aneja et al. 2008, Fowler et al.
713 2013). Ammonia does not have a long atmospheric lifetime, and generally reacts with gaseous acids to form
714 ammonium compounds, which may persist in the atmosphere as an aerosol (Aneja et al. 2008, Fowler et al.
715 2013). The most common atmospheric acids are sulfuric, nitric, and hydrochloric acid, making ammonium
716 nitrate, ammonium sulfate, and ammonium chloride the primary components of these atmospheric
717 ammonium aerosols (Stevenson et al. 2006, Aneja et al. 2008, Fowler et al. 2013). Atmospheric ammonium
718 aerosols are deposited during precipitation events in a process known as wet deposition (Aneja et al. 2008,
719 Fowler et al. 2013). In the process of wet deposition, the ammonium aerosols are incorporated into
720 precipitation (e.g., rain, snow) which redistribute the ammonium compounds to land and water surfaces
721 during the precipitation process (Aneja et al. 2008, Fowler et al. 2013).

722

723 Ammonium ions are more environmentally stable than ammonia due to the higher boiling and sublimation
724 points of ionic ammonium compounds relative to ammonia (Silberberg 2003, Shriver and Atkins 2008).
725 However, ammonium ions in the environment can undergo ammonium volatilization reactions, which
726 reform the more volatile ammonia form, as discussed previously in Equation 3 (Bateman and Kelly 2007,
727 Fowler et al. 2013, Chung et al. 2017, Dari et al. 2018). The rate of ammonia volatilization is dependent on
728 environmental conditions, with faster rates occurring at temperatures above 70 °F, wet soils, and in alkaline
729 soils (Jones et al. 2013, Dari et al. 2018). Once ammonium is converted to ammonia, it can readily move into
730 the atmosphere, as described above.

731

732 Due to the high water solubility of ammonium, nitrite, and nitrate ions, these compounds are prone to
733 leaching from the soil and often migrate into marine environments (Howrath et al. 2002, Silberberg 2003,
734 Gaskell and Smith 2007, Aneja et al. 2008, Erisman et al. 2008, Howrath 2008, Fowler et al. 2013, Bindraben
735 et al. 2014, Anas et al. 2020). Ammonia and ammonium ions that remain in soil and marine environments
736 are typically oxidized through nitrification processes by plants and microorganisms (EFSA 2008, Fowler et

737 al. 2013). The nitrification of ammonia and ammonium produces nitric oxide (nitrogen monoxide [NO]),
738 nitrous oxide, or negatively charged nitrite (NO₂⁻) and nitrate (NO₃⁻) ions depending on the plant and
739 microorganism, as well as environmental conditions (Fowler et al. 2013, Spiertz, 2009, Masclaux-Daubresse
740 et al. 2010, Bindraban et al. 2014, Anas et al. 2020). With the exception of nitrous oxide described above, the
741 nitrification products are incorporated into biomolecules or undergo further metabolism to the
742 thermodynamic sink of dinitrogen, which is released into the atmosphere (Fowler et al. 2013, Anas et al.
743 2020).

744
745 **Evaluation Question #5: Describe the toxicity and mode of action of the substance and of its breakdown**
746 **products and any contaminants. Describe the persistence and areas of concentration in the environment**
747 **of the substance and its breakdown products (7 U.S.C. § 6518 (m) (2)).**
748

749 There are no toxicological reports on ammonia extract. However, ammonia extract is chemically identical
750 to synthetic ammonia and ammonium compounds, which are discussed below.

751
752 As described in Evaluation Question 4, ammonia, ammonium ions, and most of their breakdown products
753 are readily incorporated or metabolized by plants and microorganisms for the production of amino acids
754 and other biomolecules. However, the high water solubility of ammonia and ammonium, nitrite, and
755 nitrate ions makes them prone to leaching into marine environments (Howrath et al. 2002, Silberberg 2003,
756 Aneja et al. 2008, Erisman et al. 2008, Howrath 2008, Fowler et al. 2013, Bindraben et al. 2014, Anas et al.
757 2020). While these compounds may be metabolized by aquatic organisms, the over-abundance of these
758 nutrients leads to eutrophication, making ammonia and ammonium toxic to aquatic life (Howrath 2008,
759 Spiertz 2009, Fowler et al. 2013). The influx of high concentration of nitrogen nutrients also leads to algal
760 blooms that are harmful to other aquatic life by reducing oxygen concentrations and result in hypoxic and
761 anoxic environments (Howrath 2008).

762
763 As discussed in Evaluation Question 4, ammonia, ammonium, and their breakdown compounds have
764 relatively short lifetimes in the environment, with the exception of nitrous oxide (Aneja et al. 2008, Fowler
765 et al. 2013). Unlike other atmospheric compounds linked with ammonia and ammonium compounds,
766 nitrous oxide has a long atmospheric lifetime, lasting up to 120 years (Vitousek et al. 1997, Howrath 2008,
767 Fowler et al. 2013).

768
769 **Evaluation Question #6: Describe any environmental contamination that could result from the**
770 **petitioned substance's manufacture, use, misuse, or disposal (7 U.S.C. § 6518 (m) (3)).**
771

772 *Production of ammonia extract*
773

774 The production of ammonia extract results in the release of ammonia to the environment. This result is
775 expected due to the inability of ammonia stripping and other isolation processes to capture 100% of the
776 total ammonia content of feedstocks (Folino et al. 2020). The efficiency of ammonia stripping is dependent
777 on the feedstock and particular isolation conditions but is generally reported to capture a range of 17–95%
778 of total ammonia content, with a 90% recovery considered acceptable (Kinidi et al. 2018, Folino et al. 2020,
779 Lorick et al. 2020). The remaining ammonia content is lost to the environment either as a gas, or as residual
780 ammonia and ammonium ions that remain in the treated feedstock effluent.

781
782 If not properly treated, the residual feedstock material and its effluent may result in contamination. These
783 feedstocks are wide-ranging, and include a variety of agricultural and biological wastes, including
784 manures, sewage sludge, and animal remains (Kinidi et al. 2018). In addition to the initial precautions
785 relating to these feedstocks, the use of alkaline materials to increase the pH of the feedstock require
786 neutralization and careful handling (Kinidi et al. 2018, Folino et al. 2020, Lorick et al. 2020).

787
788 The release of ammonia and ammonium compounds to the atmosphere directly contributes to atmospheric
789 contamination through the degradation of air quality and visibility due to the formation of ammonium
790 aerosols, as described in more detail in Evaluation Question 4 (Aneja et al. 2008, Fowler et al. 2013,
791 Bindraban et al. 2014). Additionally, the production of nitric oxide and nitrous oxide decomposition

792 products discussed in Evaluation Question 4 contributes to atmospheric pollution (Erisman et al. 2008,
793 Fowler et al. 2013, Anas et al. 2020). The atmospheric deposition of ammonia (dry) and ammonium (wet) to
794 terrestrial and marine environments was discussed in Evaluation Question 4 and would also result in soil
795 and water contamination (Aneja et al. 2008, Howrath 2008, Fowler et al. 2013).

796
797 *Use of ammonia extract*

798
799 There are no reports of ammonia extract in relation to environmental contamination. However, ammonia
800 extract is chemically identical to synthetic ammonia and ammonium compounds, which are discussed
801 below.

802
803 Nitrogen fertilizer, the primary product of synthetic ammonia produced via the Haber-Bosch process,
804 contributes to environmental contamination. The primary issue with nitrogen fertilizer contamination is
805 over-application, although ineffective application of fertilizers is also a contributing factor (Howrath 2008,
806 Fowler et al. 2013). Over-application of fertilizer is driven by the dramatic improvements in crop yield,
807 which create economic incentives to continue application to drive yields up even more (Spiertz 2009). The
808 over-application of nitrogen fertilizers puts more nutrients in the soil than can be taken up by crops. The
809 high water solubility of ammonia and ammonium compounds result in excess nutrients leaching into
810 water systems, which drive eutrophication (Howrath 2008, Spiertz 2009, Fowler et al. 2013, Bindraban et al.
811 2014, Anas et al. 2020). High concentrations of nitrogen fertilizers also promote emission of ammonia into
812 the atmosphere through either direct migration or ammonium volatilization (Equation 3) (Spiertz 2009,
813 Fowler et al. 2013, Dari et al. 2018). Studies have shown that over-application of nitrogen fertilizers results
814 in a dramatic loss (20–80%) of these nutrients to the environment, predominantly through the atmospheric
815 and aquatic pathways discussed in Evaluation Question 4 (Spiertz 2009, Fowler et al. 2013, Bindraban et al.
816 2014, Anas et al. 2020). The propensity of ammonia and ammonium to migrate from the applied soil to the
817 atmosphere and water systems results in the contamination of ecosystems outside of those receiving the
818 fertilizer, a phenomenon known as unintended fertilization (Erisman et al. 2008, Howrath 2008, Fowler et
819 al. 2013).

820
821 **Evaluation Question #7: Describe any known chemical interactions between the petitioned substance**
822 **and other substances used in organic crop or livestock production or handling. Describe any**
823 **environmental or human health effects from these chemical interactions (7 U.S.C. § 6518 (m) (1)).**

824
825 There are no reports of ammonia extract in relation to environmental or human health effects. However,
826 ammonia extract is chemically identical to synthetic ammonia and ammonium compounds, which are
827 discussed below.

828
829 Ammonia extract may combine ammonia and ammonium compounds. Ammonia is a weak base, making it
830 potentially reactive with acidic substances used in organic agricultural production. These include naturally
831 occurring amino acids (with acidic side chains), natural acids including acetic acid, citric acid, fulvic acids,
832 gibberellic acid, humic acids, and lactic acid, and other acidic soil amendments such as sulfur (NOP 2016c,
833 Timberlake 2016).

834
835 Ammonium ions are weak acids and may react with basic compounds used in organic agriculture
836 production. These include the use of soil pH adjusters such as calcium carbonate (limestone) and lime, soil
837 amendments including ash, wood ash, and biochar (NOP 2016c). The interactions between these
838 substances and ammonium ions may neutralize them, making them no longer effective to increase soil
839 alkalinity. Additionally, neutralization reactions between ammonium ions and basic substances would also
840 result in the volatilization of the ammonium ion to form ammonia, as described in Equation 3.

841
842 Application of ammonium ions to soil will reduce soil pH, leading to soil acidification (Aneja et al. 2008,
843 Fowler et al. 2013, Geisseler and Scow 2013, Anas et al. 2020). The lower soil pH resulting from the addition
844 of ammonium ions increases the solubility of soil micronutrients, specifically positively charged metal ions
845 (Vitousek et al. 1997, Silberberg 2003). The increased solubility of these metal ions increases their
846 bioavailability and may also increase crop yields. However, the increased solubility of these ions may also

847 result in their loss to run-off, leaching into nearby marine environments (Vitousek et al. 1997). While
848 increasing the solubility of metal ions improves the bioavailability of nutrients, it also improves the
849 solubility of plant toxic aluminum ions and other heavy metal ions (Vitousek et al. 1997, Ma et al. 2001).

850
851 **Evaluation Question #8: Describe any effects of the petitioned substance on biological or chemical**
852 **interactions in the agro-ecosystem, including physiological effects on soil organisms (including the salt**
853 **index and solubility of the soil), crops, and livestock (7 U.S.C. § 6518 (m) (5)).**
854

855 There are no reports of ammonia extract in relation to environmental interactions. However, ammonia
856 extract is chemically identical to synthetic ammonia and ammonium compounds, which are discussed
857 below.

858
859 As discussed in Evaluation Question 4, ammonia and ammonium compounds can readily migrate from the
860 applied soil system into the atmosphere and marine environments. When ammonia and ammonium
861 compounds remain in their applied soils, they also induce changes to the local environment. The acidic
862 nature of ammonium ions is recognized as a cause of soil acidification, reducing the soil pH (Aneja et al.
863 2008, Fowler et al. 2013, Geisseler and Scow 2013, Anas et al. 2020). These pH changes result in changes to
864 the solubility and bioavailability of other nutrients, affecting both crops and soil organisms (Spiertz 2009,
865 Anas et al. 2020). Changes to soil pH may also have negative impacts on the viability of soil organisms,
866 including earthworms and various microbial populations (Edwards et al. 1995, Bünemann et al. 2006,
867 Fowler et al. 2013, Geisseler and Scow 2013, Bindraban et al. 2014). High soil concentrations of ammonia
868 and ammonium have been shown to retard the natural nitrogen fixation processes of plants (Erisman et al.
869 2008, Spiertz 2009, Fowler et al. 2013). This shift in natural ammonia production reduces the natural
870 efficiency of the soil, making it more reliant on continued nitrogen inputs (Erisman et al. 2008, Spiertz 2009,
871 Fowler et al. 2013).

872
873 While bioavailable nitrogen is also important for the function of microorganisms, high concentrations of
874 ammonia and ammonium compounds result in changes to the native soil communities. These changes vary
875 based on the initial soil communities and may result in either an increase or decrease in total population.
876 However, while there are cases of population growth in some communities, the application of nitrogen
877 fertilizers is associated with decreases to the diversity of these microbial communities (Erisman et al. 2008,
878 Spiertz 2009, Fowler et al. 2013, Bindraban et al. 2014, Anas et al. 2020). Decreases to the diversity of soil
879 microbial communities are closely linked to changes in pH but may also favor microbes capable of
880 metabolizing nitrogen inputs (Fowler et al. 2013, Geisseler and Scow 2013).

881
882 **Evaluation Question #9: Discuss and summarize findings on whether the use of the petitioned**
883 **substance may be harmful to the environment (7 U.S.C. § 6517 (c) (1) (A) (i) and 7 U.S.C. § 6517 (c) (2) (A)**
884 **(i)).**
885

886 There are no reports of ammonia extract in relation to environmental impacts. However, ammonia extract
887 is chemically identical to synthetic ammonia and ammonium compounds, which are discussed below.

888
889 As discussed in Evaluation Questions 4–8, ammonia and ammonium compounds are capable of spreading
890 through the environment through the atmosphere and water systems. The movement of these compounds
891 and their degradation products through these systems provides various sources of environmental
892 contamination. The soil systems that receive these compounds may result in changes to plant activity and
893 decreases to the biodiversity of soil microorganisms (Erisman et al. 2008, Fowler et al. 2013, Anas et al.
894 2020). Additionally, the ability of these compounds and their degradation products to readily move
895 through the atmosphere provides the potential for unintended fertilization of neighboring ecosystems
896 (Erisman et al. 2008, Spiertz 2009, Fowler et al. 2013).

897
898 The release of ammonia to the atmosphere directly contributes to ozone depletion and global warming
899 (ammonia is a greenhouse gas) (Aneja et al. 2008, Erisman et al. 2008, Spiertz 2009, Bindraban et al. 2014,
900 Anas et al. 2020). Ammonia and ammonium compounds contribute to the degradation of air quality and
901 visibility due to the formation of ammonium aerosols, as described in more detail in Evaluation Question 4.

902 (Aneja et al. 2008, Bindraban et al. 2014). The production of nitric oxide and nitrous oxide contribute to
903 ozone depletion (Erisman et al. 2008, Spiertz 2009, Anas et al. 2020).

904
905 The atmospheric deposition of ammonia (dry) and ammonium (wet) to terrestrial and marine
906 environments was discussed in Evaluation Question 4 and would also result in soil and water
907 contamination (Aneja et al. 2008, Howrath 2008, Spiertz 2009, Fowler et al. 2013). The movement of excess
908 nutrients from soils and the atmospheres into marine environments results in eutrophication (Aneja et al.
909 2008, Erisman et al. 2008, Howrath 2008, Spiertz 2009, Fowler et al. 2013, Bindraban et al. 2014). In this
910 process, the abundance of nutrients drives algal blooms and reduce oxygen concentrations (Aneja et al.
911 2008, Erisman et al. 2008, Howrath 2008). As a result, the influx of ammonia and ammonium compounds
912 into marine environments is toxic to aquatic life ranging from microorganisms to fish (Aneja et al. 2008,
913 Spiertz 2009).

914
915 The activity of ammonia and ammonium compounds in soil systems is dependent on the environmental
916 conditions. Acidic soils generally result in higher stability of both compounds as ammonium ions are less
917 likely to undergo volatilization reactions and ammonia is more likely to be converted to the more stable
918 ammonium form (Dari et al. 2018). Relatively dry soils also tend to provide more stability to ammonia and
919 ammonium compounds and are more likely to remain in the applied soil or be metabolized by crops or soil
920 organisms (Aneja et al. 2008, Dari et al. 2018). However, alkaline soils typically enhance ammonium
921 volatilization reactions converting ammonium into the more labile ammonia, which migrates into the
922 atmosphere (Dari et al. 2018). Wet soils also tend to increase the degree of environmental contamination by
923 facilitating volatilization reactions, filling soil pores and preventing nitrogen absorption, and solubilizing
924 the compounds which leach into adjoining water systems (Dari et al. 2018). The soil temperature also
925 effects the degree of ammonia lost to the atmosphere and the rate of ammonium volatilization reactions.
926 Increased temperatures release larger amounts of ammonia to the atmosphere, with high emission above
927 70 °F, although measurable ammonia emission also occurs below freezing at 30 °F (Jones et al. 2013, Dari et
928 al. 2018).

929
930 **Evaluation Question #10: Describe and summarize any reported effects upon human health from use of**
931 **the petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (i), 7 U.S.C. § 6517 (c) (2) (A) (i) and 7 U.S.C. § 6518**
932 **(m) (4)).**

933
934 There are no reports of ammonia extract in relation to human health effects. However, ammonia extract is
935 chemically identical to synthetic ammonia and ammonium compounds, which are discussed below.

936
937 Ammonium is a positive ion and its effects on human health are dependent on the identity of the
938 remaining negative portion of the ionic compound (Silberberg 2003, Timberlake 2016). Ammonium ions are
939 prevalent in human metabolism and play a critical role in the citric acid (or Krebs) cycle (Flomenbaum et al.
940 2002, EFSA 2008, Timberlake 2016).

941
942 Ammonia is classified as a respiratory irritant (Flomenbaum et al. 2002, Airgas 2019). When ammonia is
943 ingested, it reacts rapidly with water in airways producing ammonium hydroxide and inducing severe
944 irritation of upper airways (Flomenbaum et al. 2002). Long-term exposure to gaseous ammonia or high
945 concentration exposures may result in tracheobronchial or pulmonary inflammation (Flomenbaum et al.
946 2002). Repetitive exposure to high ammonia concentrations or chronic exposure to lower concentrations
947 may cause pulmonary fibrosis (Flomenbaum et al. 2002). If directly inhaled or ingested, ammonia may
948 cause esophageal burns, with the severity of the burns dependent on the volume of ammonia ingested
949 (Flomenbaum et al. 2002).

950
951
952
953
954
955

956 **Evaluation Question #11: Describe all natural (non-synthetic) substances or products which may be**
957 **used in place of a petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (ii)). Provide a list of allowed**
958 **substances that may be used in place of the petitioned substance (7 U.S.C. § 6518 (m) (6)).**

959
960 *Manure*

961
962 There are many natural soil amendments that can be used to deliver nitrogen for crops. Manure is a source
963 of nitrogen compounds, including ammonia, ammonium ions, and urea, which are biological waste
964 compounds (Mikkelsen and Hartz 2008, Timberlake 2016, Anas et al. 2020). However, manure has a
965 relatively low level of biologically available nitrogen compared to ammonia extract. The biologically
966 available forms of nitrogen in manures may also lead to similar issues with nutrient leaching as ammonia
967 extract, potentially polluting surrounding water systems and leading to atmospheric ammonia emissions
968 (Aneja et al. 2008, Mikkelsen and Hartz 2008, Spiertz 2009). Manure from both organic and conventional
969 livestock is permitted for use in the production of organic crops (NOP 2016c). However, the availability of
970 manure may be limited regionally due to the continued segregation of crop and animal agricultural
971 production (Lorick et al. 2020).

972
973 *Crop residues and compost*

974
975 In addition to manure, crop residues and compost may be added as a source of bioavailable nitrogen. This
976 includes the direct integration and composting of both manure and other organic agricultural wastes
977 (Gaskell et al. 2007, Yang et al. 2015, Anas et al. 2020). The high protein and amino acid content of these
978 feedstocks allows for their conversion to ammonia and ammonium compounds through anaerobic
979 digestion and metabolism by soil microorganisms (Wang et al. 2008, Latvala et al. 2013). When composts
980 do not include manures, they are generally low in nitrogen containing compounds (Gaskell and Smith
981 2007, Gaskell et al. 2007). The low concentrations of nitrogen in crop residues and composts are also
982 generally found in forms with limited bioavailability compared to manures. The low bioavailability of
983 nitrogen found in most composts requires mineralization processes to transform nitrogen into accessible
984 ammonium and nitrate ions (Bünemann et al. 2006, Gaskell and Smith 2007, Gaskell et al. 2007, Mikkelsen
985 and Hartz 2008, Yang et al. 2015). The low-level of nitrogen and its limited bioavailability in crop residue
986 and compost make it a poor short-term alternative to ammonia extract (Gaskell and Smith 2007).

987
988 The incorporation of crop residues and compost provides a potential long-term alternative to ammonia
989 extract and other nitrogen fertilizers. Nitrogen content in compost is slowly released through
990 mineralization processes in the soil, primarily facilitated by its metabolism by microorganisms in the soil
991 (Bünemann et al. 2006, Gaskell et al. 2007, Mikkelsen and Hartz 2008, Yang et al. 2015). Unlike ammonia
992 extract, the use of compost also contributes to soil organic matter, and available carbon, phosphorous, and
993 micronutrients, as well as soil microorganism populations and activities (Bünemann et al. 2006, Gaskell
994 and Smith 2007, Yang et al. 2015). The incorporation of compost into the agro-ecosystem has been reported
995 to improve soil characteristics, specifically water holding capacity and cation exchange capacity (CEC)
996 (Gaskell et al. 2007). Increased soil CEC allows it to more effectively retain cations, including ammonium
997 ions and metal cations required as micronutrients (e.g., iron [Fe], copper [Cu], zinc [Zn]) (Gaskell et al.
998 2007).

999
1000 Ammonium and nitrate ions transferred to soil from crop residues and compost, and subsequent
1001 mineralization processes, have the same chemical and physical properties as those from ammonium
1002 extract. Therefore, the incorporation of compost could potentially contribute to leaching of ammonia,
1003 ammonium, nitrate, and nitrogen oxides into surrounding water systems and the atmosphere (Gaskell et
1004 al. 2007). The reduced nitrogen content in compost and the reduced bioavailability of their nitrogen forms
1005 make them less likely to contribute to nitrogen contamination compared to ammonia extract. However,
1006 crop residues and compost are relatively high in phosphorous sources (Gaskell and Smith 2007, Gaskell et
1007 al. 2007). While phosphorous compounds are important macronutrients for plant growth, over application
1008 may result in phosphorous leaching into the environment (Gaskell and Smith 2007, Gaskell et al. 2007,
1009 Mikkelsen and Hartz 2008). Phosphorous in soil may leach into neighboring aquatic systems, contributing
1010 to undesired algal blooms (Mikkelsen and Hartz 2008). Phosphorous leaching is a potential concern in the

1011 long-term application of crop residues, which may have relatively high concentrations of bioavailable
1012 phosphorous (Gaskell et al. 2007).

1013
1014 *Chilean nitrate (sodium nitrate)*

1015
1016 Chilean nitrate (mined sodium nitrate) is a natural source of bioavailable nitrate ions (Mikkelsen and Hartz
1017 2008). Chilean nitrate offers a natural alternative to ammonia extract as a nitrogen fertilizer, and is the
1018 historical source of nitrogen fertilizer prevalent before the advent of the Haber-Bosch process (Wisniak and
1019 Garces 2001). However, the industrial prominence of the Haber-Bosch process reduced the share of Chilean
1020 nitrate to less than 0.1% by the 1990s, with most remaining applications being in organic agriculture
1021 (Wisniak and Garces 2001). Chilean nitrate is a mineral source of sodium nitrate, mined from deserts in the
1022 Tarapaca region of Chile (Wisniak and Garces 2001). Chilean nitrate is approximately 16% sodium nitrate
1023 with feldspar and calcium sulfate; and sodium, potassium, and magnesium ores being other compounds
1024 found in its chemical composition (Wisniak and Garces 2001, Gaskell et al. 2007, Mikkelsen and Hartz
1025 2008).

1026
1027 Nitrate has been shown to be less toxic to terrestrial and aquatic organisms than ammonium ions, although
1028 it is toxic to some species at high concentrations (Schuyttema and Nebeker 1999). However, nitrate is more
1029 likely to contribute to environmental contamination than ammonium, and is the nitrogen primary
1030 compound associated with leaching into aquatic systems (Gaskell and Smith 2007). Sodium nitrate is
1031 highly water soluble, and may leach into aquatic systems as run-off (Silberberg 2003, Gaskell et al. 2007).
1032 Nitrate also contributes to atmospheric contamination in the form of various nitrogen oxide compounds
1033 that are formed through denitrification reactions (Gaskell and Smith 2007). Nitrate ions are more likely to
1034 contribute to aquatic pollution, as nitrate is the primary form that nitrogen leaches into water systems
1035 (Gaskell and Smith 2007). While ammonium ions are also able to leach into water systems, aquatic
1036 contamination from ammonium more frequently occurs through nitrate decomposition products formed
1037 via mineralization processes (Gaskell and Smith 2007, Gaskell et al. 2007). The sodium component of
1038 Chilean nitrate may contribute to increased soil salinity with prolonged use (NOSB 2011). Nitrate over
1039 application may also contribute to contamination of leafy vegetable crops. Several studies have reported
1040 the accumulation of nitrate in vegetable leaves when Chilean nitrate were used as a fertilizer (Zhang et al.
1041 1990, Wang et al. 2008).

1042
1043 Unlike ammonia extract and the other alternatives discussed here, Chilean nitrate is a mined substance
1044 (Gaskell and Smith 2007). The environmental concerns of the mining process and the potential to
1045 contribute to leaching from the agro-ecosystem have resulted in NOP's limit of Chilean nitrate to "no more
1046 than 20% of the crop's total nitrogen requirement," in 7 CFR 205.602 (NOSB 2011).

1047
1048 *Organic fertilizers*

1049
1050 Many substances derive from natural products that are allowed as organic fertilizers, including fish meal,
1051 liquid fish residues, feather meal, bird or bat guano, alfalfa meal, soybean meal, bone meal, kelp, seaweed,
1052 blood meal, and meat meal (Gaskell and Smith 2007, Gaskell et al. 2007, Mikkelsen and Hartz 2008). Like
1053 crop residues and compost, organic fertilizers require additional mineralization processes and provide a
1054 slow release of nitrogen, which is primarily present in complex molecules. However, these organic
1055 fertilizers provide more nitrogen than compost due to the higher nitrogen in their chemical composition,
1056 ranging between 2 and 14% (Gaskell and Smith 2007, Gaskell et al. 2007, Mikkelsen and Hartz 2008). Field
1057 reports have shown that guano and fish-based fertilizers produce the most efficient initial delivery of
1058 bioavailable nitrogen compared to other organic fertilizers (Hartz and Johnstone 2006, Gaskell and Smith
1059 2007, Mikkelsen and Hartz 2008).

1060
1061 Like crop residues and compost, organic fertilizers also contribute to increased soil organic matter, CEC
1062 capacity, and other nutrients and micronutrients (Gaskell and Smith 2007, Gaskell et al. 2007). Unlike
1063 nitrogen fertilizers used in conventional agriculture, organic fertilizers have been reported to have minimal
1064 negative to long-term positive effects (Bünemann et al. 2006). However, the higher nitrogen content and

1065 bioavailability of nitrogen compounds make organic fertilizers more prone to environmental and
1066 atmospheric contamination than crop residues and compost (Gaskell and Smith 2007).

1067
1068 There are no synthetic substances that have been approved for organic crop production that provide an
1069 alternative for ammonia extract.

1070
1071 **Evaluation Question #12: Describe any alternative practices that would make the use of the petitioned**
1072 **substance unnecessary (7 U.S.C. § 6518 (m) (6)).**

1073
1074 Crop rotation is a traditional technique to ensure soil viability and health. This can be especially useful if
1075 soybeans or other legumes are included in these rotations. Legumes are noted for their ability to facilitate
1076 nitrogen fixation, converting atmospheric dinitrogen into bioavailable nitrogen, such as ammonium, and
1077 delivering it into the soil (Wang et al. 2008, Spiertz 2009, Anas et al. 2020). Moreover, legumes and other
1078 nitrogen-fixing plants produce higher quantities of bioavailable nitrogen when there are low soil
1079 concentrations of ammonia and ammonium (Erisman et al. 2008, Spiertz 2009, Fowler et al. 2013). These
1080 results allow the influx of bioavailable nitrogen, which may be introduced into the soil directly by legumes
1081 on a rotating basis based on the specific environmental and crop requirements.

1082
1083 In addition to crop rotation, intercropping offers the potential for direct introduction of natural
1084 bioavailable nitrogen from legumes to other crops by growing them alongside one another (Anas et al.
1085 2020). Intercropping has been shown to improve crop yields, which have been shown to be less dependent
1086 on nutrient inputs compared to monocropping systems (Speirtz 2009, Anas et al. 2020).

1087
1088 The incorporation of legumes, grasses, clover, and alfalfa as cover crops have been reported to improve
1089 nitrogen content of agricultural soils (Gaskell and Smith 2007, Wang et al. 2008, Mikkelsen and Hartz 2008,
1090 Scavo et al. 2020). Crop cover are plants grown between growing cycles of agricultural cash crops, rather
1091 than leaving the soil uncovered (Gaskell et al. 2007, Scavo et al. 2020). Legumes contribute to soil nitrogen
1092 by the same nitrogen-fixation mechanism described above in the discussion of crop rotations and
1093 intercropping. Legumes may be planted alone as cover crops, or in combination with grasses. The
1094 combination of legumes with grasses reduces weed growth and prevents excess nitrates in the soil from
1095 leaching into neighboring aquatic systems (Gaskell and Smith 2007, Gaskell et al. 2007). The use of clover
1096 and alfalfa as cover crops have been reported to increase accessible soil nitrogen content by promoting
1097 mineralization processes that convert nitrogen in proteins, amino acids, and other complex molecules into
1098 the bioavailable ammonium and nitrate ions (Gaskell et al. 2007, Wang et al. 2008, Scavo et al. 2020). In
1099 addition to promoting and regulating nitrogen soil content, cover cropping also promotes increases to soil
1100 organic matter, increases CEC properties, and prevents soil erosion (Gaskell and Smith 2007, Gaskell et al.
1101 2007, Mikkelsen and Hartz 2008, Scavo et al. 2020). However, applications of cover crops may be limited by
1102 regional climate, and require temperatures amenable to the growth of cover crops between agricultural
1103 growing seasons (Gaskell et al. 2007).

1104

Report Authorship

1105

1106

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1109

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1113

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1115 Personal Conflicts of Interest for Contractor Employees Performing Acquisition Functions.

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