AMMONIA – ESSENTIAL FOR LIFE

Ammonia is a naturally occurring substance that is contained in all life forms, from plants to animals to humans. Life forms could not have evolved and cannot survive without it. Ammonia is used extensively in the production of a wide range of food and beverages. The following excerpts from government studies, academic journals and industry research outlines the vital role ammonia plays in our daily lives. In order to obtain access to the full government studies, academic journals and industry research referenced, please see page 13.

- The human body naturally produces ammonia every day.
- Ammonia naturally enters and leaves your body every day.
- Ammonia is essential for maintaining the acid-base balance in your body and so keeps you healthy.
- Ammonia is a critical element in the transition of Nitrogen from N_2 to N_1. Nitrogen in the form of N_1 is an essential element for life.
- Ammonia has been used for many years as a processing aid in thousands of food and beverage products.
- Ammonia is present in foods. Ammonia in peanut butter (489 ppm), American cheese (813 ppm), and domestic blue cheese (1,376 ppm). The typical ammonia aroma of Brie and Camembert cheeses indicates higher levels of ammonia.
- Meat that has been pH enhanced with ammonium hydroxide is a natural addition to the wide range of consumer food products that include ammonia in their processing. Of all the foods that contain ammonium hydroxide, these meats have levels lower than other foods including the before mentioned American cheese, domestic blue cheese, peanut butter and gourmet brie and camembert cheeses.
- Meat that has been pH enhanced has been validated to produce significant reductions in microbial counts compared to non-enhanced meat.
- As with EVERY substance, the amount (*i.e.*, the dose) determines whether the substance has a beneficial or potentially harmful effect.[1]

We invite you to learn more in the following pages about how ammonia is an essential part of our lives and how we cannot live without it.

[1]An oral dose of Ammonia sufficient to be toxic would not be consumed, as the substance would be extremely distasteful long before a toxic level was achieved.

AMMONIA – ESSENTIAL FOR LIFE

1. A Key Component To Evolution

Scientists have long acknowledged that ammonia was an essential component in the evolution of all life forms, and that those forms could not presently survive without it. Earth's first microbes, which emerged about 3.5 billion years ago, had no ability to metabolize nitrogen, in the form of N_2 gas, writes David W. Wolfe in an article in Natural History magazine[2]. However, a unique group of bacteria "invented a way to convert or fix N_2 gas into ammonia (NH_3, a usable form of nitrogen, in combination with hydrogen). Essentially all the nitrogen contained within the proteins and genes of plants, animals and humans has, at one time or another, been funneled through these nitrogen-fixing microbes, says Wolfe.

Ammonia's essential role in the evolution and survival of all life forms is regularly referenced in literature published by the U.S. federal government. "Ammonia is a naturally-occurring compound which is a key intermediate in the nitrogen cycle," says the U.S. Department of Health and Human Services' Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), in a toxicological profile for ammonia.[3] Under normal circumstances, ammonia is essential for many biological processes, it says. Ammonia is the most abundant basic gas in the environment.

Ammonia is very important to plant, animal and human life, says ATSDR.[4] It is found in water, soil and air, and is a source of essential nitrogen for plants and animals. Nitrogen is a critical element for life, and is one of the six bulk elements (and the fourth most common) in the human body.[5] Most of the ammonia in the environment comes from the natural breakdown of organic matter. Ammonia does not last long in the environment, it says. Because it is recycled naturally, nature has many ways of incorporating and transforming ammonia.

"Since ammonia naturally occurs in the environment, we are regularly exposed to low levels of ammonia in air, soil and water," says ATSDR.[6] Ammonia exists naturally in the air at levels between one part and five parts in a billion parts of air (ppb). It is commonly

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[2] *Out Of Thin Air*, authored by David W. Wolfe, Natural History, September 2001.
[3] *Toxicological Profile for Ammonia,* published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), 1991.
[4] *Toxicological Profile for Ammonia,* published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), 1991.
[5] http://www.mii.org/periodic/N.htm
[6] *Toxicological Profile for Ammonia,* published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), 1991.

1. A Key Component To Evolution (continued)

found in rain water. The ammonia level in rivers and bays are usually less than 6 parts of ammonia in a million parts of water (ppm). Soil typically contains about 1 to 5 ppm of ammonia. The levels of ammonia vary throughout the day, as well as from season to season. Generally, ammonia levels are highest in the summer and spring, when nature is most active, says ATSDR.

Ammonia's essential role in all life forms is reiterated by a Public Health Statement published by ATSDR in September 2004.[7] Ammonia is made both by humans and by nature, it says. "Ammonia is essential for mammals and is necessary for making DNA, RNA and proteins. It also plays a part in maintaining acid-base balance in tissues of mammals," it says.

[7] *Public Health Statement – Ammonia, CAS#: 7664-41-7*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), September 2004.

2. Your Body Produces Ammonia Daily

Ammonia is naturally produced and is used by all mammals in their normal metabolism, says U.S. Department of Health and Human Services' Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR).[8] "Ammonia is produced within a person's body each day. Most of this ammonia is produced by organs and tissues but some is produced by bacteria living inside our intestines."

Ammonia is formed in the human intestinal tract by the biological degradation of nitrogenous matter in quantities of about 4 grams per day, says a 1986 report sponsored by the United Nations, the International Labor Organization and the World Health Organization.[9] Nearly all of this ammonia is absorbed (mainly passively) and is metabolized in the liver on the first passage, so that only small amounts reach the systemic circulation. Ammonia is normally present in all tissues constituting a metabolic pool, says the report. Its distribution is pH dependent, since NH_3 diffuses more easily than NH_{4+}, it says.

"Ammonia is taken up by glutamic acid in many tissues, and this will take part in a variety of transamination and other reactions, the nitrogen being incorporated in non-essential amino acids," says the UN report.[10] In the liver, ammonia is used in the synthesis of protein by the Krebs-Henseleit cycle.

"Ammonia is in a state of flux in the body, though it is present in low, steady-state concentration in body fluids," says the UN report.[11] "In animals, metabolically-produced ammonia is conjugated and excreted."

[8] See *Toxicological Profile for Ammonia* and *Public Health Statement – Ammonia, CAS#: 7664-41-7* and *Toxicological Profile for Ammonia*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), September, 2004.

[9]) Ammonia (EHC 54), International Programme on Chemical Safety, Environmental Health Criteria 54, published under the joint sponsorship of the United Nations Environmental Programme, the International Labor Organization and the World Health Organization, 1986.

[10] Ammonia (EHC 54), International Programme on Chemical Safety, Environmental Health Criteria 54, published under the joint sponsorship of the United Nations Environmental Programme, the International Labor Organization and the World Health Organization, 1986..

[11] Ammonia (EHC 54), International Programme on Chemical Safety, Environmental Health Criteria 54, published under the joint sponsorship of the United Nations Environmental Programme, the International Labor Organization and the World Health Organization, 1986.

2. Your Body Produces Ammonia Daily (continued)

Although ammonia is liberated from several tissues, including the kidneys and muscle, most of it enters the circulation from the gastrointestinal trace, and the contribution from the colon predominates, according to a 1970 paper in The American Journal of Clinical Nutrition (AJCN).[12]

In patients undergoing abdominal operations, ammonia concentrations in the portal vein are five times greater than those in the systemic circulation, says the AJCN paper (6). Thus, approximately 4 grams of ammonia may be absorbed from the gut during a 24-hour period. Presumably, this amount is incremented by ammonia that originates from dietary constituents under normal circumstances. Estimates of the amounts of ammonia produced in various regions of the human gut, calculated from the approximate data available, are shown in the following table.

Estimated ammonia production in the human gastrointestinal tract

Site	Ammonia mg/day	Percentage of total produced
Stomach	30	0.7
Duodenum	10	0.3
Jejunum (and ileum?)	1,080	25.7
Colon	3,080	73.3
Colon (basal)	(50)	
Total produced	4,200	100.0
Total excreted	50	
Total absorbed	4,150	

In health, ammonia absorbed from the gastrointestinal tract passes to the liver, where it is mainly synthesized to urea by the Krebs-Henseleit cycle, say authors W. H. J Summerskill and Enrique Wolpert, in the AJCN paper.[13] Between 15% and 30% of urea synthesized by the liver is hydrolyzed to ammonia by gastrointestinal ureases, thereby giving rise to the equivalent of 3.5 grams of ammonia during 24 hours, a significant proportion of all that is absorbed from the gut. As little as 50 mg of ammonia is excreted, they say.

[12] *Ammonia Metabolism in the Gut*, by W. H. J. Summerskill, D.M., and Enrique Wolpert, M.D., The American Journal of Clinical Nutrition, Vol. 23, No. 5, May 1970, pp 633-639.

[13] *Ammonia Metabolism in the Gut*, by W. H. J. Summerskill, D.M., and Enrique Wolpert, M.D., The American Journal of Clinical Nutrition, Vol. 23, No. 5, May 1970, pp 633-639.

2. Your Body Produces Ammonia Daily (continued)

In vitro, transport of ammonia across a membrane is governed primarily by the physiochemical principles of nonionic diffusion; write Summerskill and Wolpert (6). In solution, ammonia acts as a buffer. The free base diffuses readily because of its lipid solubility and lack of charge, whereas the ammonium being hydrated, charged, and of low lipid solubility, penetrates membranes with difficulty, they write.

The brain also produces and consumes ammonia under normal conditions, say medical researchers at Cornell University and the Memorial Sloan-Kettering Cancer Center in New York.[14] The brain contains enzymes that are capable of using and releasing ammonia. However, there is little direct information concerning the relative activity of these metabolic pathways, they say.

[14] *The Dynamics of Ammonia Metabolism in Man*, by Alan H. Lockwood, Joseph M. McDonald, Robert E. Reiman, Alan S. Gelbard, John S. Laughlin, Thomas E. Duffy and Fred Plum, Departments of Neurology and Biochemistry, Cornell University Medical Center, and Biophysics Laboratory, Memorial Sloan-Kettering Center, New York, as published in The American Society for Clinical Investigation, Volume 63, March 1979, 449-460.

3. Ammonia Enters And Leaves Your Body Daily

Ammonia is found naturally in the environment, says the U.S. Department of Health and Human Services.[15] You may be exposed to ammonia by breathing air, eating food or drinking water that contains it, or through skin contact with ammonia or ammonium compounds. Exposure to ammonia in the environment is most likely to occur by breathing in ammonia that has been released into the air.

"Ammonia can enter your body if you breathe in ammonia gas or if you swallow water or food containing ammonium salts," says DHHS.[16] "If you spill a liquid containing ammonia on your skin, a small amount of ammonia might enter your body through your skin."

"However, more ammonia will probably enter as you breathe ammonia gas from the spilled ammonia.[17] After you breathe in ammonia, you breathe most of it out again. The ammonia that is retained in the body is changed into ammonium compounds and carried throughout the body in seconds. If you swallow ammonia in food or water, it will get into your bloodstream and be carried throughout your body in seconds."

[15] *Public Health Statement – Ammonia, CAS#: 7664-41-7*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), September 2004.
[16] *Public Health Statement – Ammonia, CAS#: 7664-41-7*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), September 2004.
[17] *Public Health Statement – Ammonia, CAS#: 7664-41-7*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), September 2004.

4. Used Extensively In Food Processing

Ammonia has been approved for many years for use in the U.S. food and beverage industry. The industry uses ammonia as a source of nitrogen needed by yeast and microorganisms, says the International Institute of Ammonia Refrigeration.[18]

Other research material says that ammonia in some form is used in the manufacture of baked goods, gelatins, puddings, grain, chocolate, snack foods, reconstituted vegetables, condiments, relishes, cheeses, and non-alcoholic beverages. Ammonia is used in the process of producing soy protein concentrates / isolates, as a result, all meat and soy based products utilizing these ingredients contain increased levels of ammonia.

The use of ammonia in food and beverage production is regulated by the Food and Drug Administration under the Federal Food, Drug and Cosmetic Act. It approves use by applying the GRAS (Generally Recognized As Safe) status to various ammonia products. These include:

Ammonium Hydroxide (GRAS 21 CFR 2184.1139)
Used in the production of soy proteins and soy isolates, which are ingredients in meat products and other processed foods. Hydrochloric acid is used to precipitate the proteins. These soy proteins are then resolubilized by raising their pH with ammonium hydroxide.

Ammonium Chloride (GRAS 21 CFR 184.1138)
A replacement for sodium chloride in low sodium foods

Monammonium Glutamate (GRAS 21 CFR 582.1500)
Flavor enhancer, similar to sodium glutamate

Ammonium Carbonate or Ammonium Bicarbonate (GRAS 21 CFR 184.1137)
Coffee whiteners: pH or buffering agent to increase the pH of whitener/coffee mixture, as coffee is very acidic and whitener would precipitate instead of mixing uniformly
Flavor stabilization: used as a buffer in soft drinks and other beverages
Leavening agent: source of carbon dioxide in the baking industry. When exposed to moisture and heat, bread will rise. The magnitude of this reaction can be increased by adding an acidulant.

Ammonium Sulfate (GRAS 21 CFR 184.1143)
Used in the production of hydrolyzed milk protein to precipitate any dark pigments. Also used in the production of yeast extracts

Ammonium Alginate (GRAS 21 CFR 184.1133)
Stabilizer and thickener in confections, frostings, gelatins, puddings, jams, jellies, fats and oils

[18] *Ammonia Data Book*, published by the International Institute of Ammonia Refrigeration, Washington, D.C., December 1992.

4. Used Extensively In Food Processing (continued)

A Food And Drug Administration (FDA) survey indicated that in 1960 3,000 metric tons (MT) of ammonia compounds were used, in 1970 that number doubled to 6,000 metric tons (FASEB 1974) and utilization has continued to increase. These comprised: ammonium bicarbonate 317 MT; ammonium carbonate 24 MT; ammonium hydroxide 525 MT; monobasic ammonium phosphate 52 MT; dibasic ammonium phosphate 434 MT; ammonium sulfate 1,468 MT. Information for ammonium chloride was not available.

The FDA states that the levels of ammonia and ammonium compounds normally found in food do not pose a health risk.[19] Maximum allowable levels in processed foods are as follows: 0.04-3.2% (400 to 32,000 ppm) ammonium bicarbonate in baked goods, grain, snack foods and reconstituted vegetables; 2.0% (20,000 ppm) ammonium carbonate in baked goods, gelatins and puddings; 0.001% (10 ppm) ammonium chloride in baked goods and 0.8% (8,000 ppm) in condiments and relishes; 0.6-0.8% (6,000 to 8,000 pppm) ammonium hydroxide in baked goods, cheeses, gelatins, and puddings; 0.01% (100 ppm) in monobasic ammonium phosphate in baked goods; 1.1% (11,000 ppm) dibasic ammonium phosphate in baked goods, 0.003% (30 ppm) in nonalcoholic beverages and 0.012% (120 ppm) in condiments and relishes.[20]

Research has been conducted over the past 90 years regarding ammonia's effect on food, notes the International Institute of Ammonia Refrigeration.[21]

[19] *Public Health Statement – Ammonia, CAS#: 7664-41-7*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), September 2004.
[20] *Public Health Statement – Ammonia, CAS#: 7664-41-7*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), September 2004..
[21] *Ammonia Data Book*, published by the International Institute of Ammonia Refrigeration, Washington, D.C., December 1992.

5. Maintains the acid-base balance in your body

Ammonia plays a vital role in keeping your body healthy by helping to maintain your acid-base balance. Extensive work has been completed on the metabolism of ammonias and its participation in the glutamine cycle and the urea cycle, says the U.S. Department of Health and Human Services.[22] It and other scientific bodies cite the importance of ammonia's conversion into glutamine in maintaining the body's proper acid-base balance by maintaining the health and integrity of the gastrointestinal tract.

Ammonium ion is endogenously produced in the human digestive tract, much of it arising from the bacterial degradation of nitrogenous compounds from ingested foods, says DHHS.[23] About 4,220 mg per day are produced, greater than 70% of which is synthesized or liberated within the colon. The total amount absorbed is about 4,150 mg per day, or 99% of the amount produced (Summerskill and Wolpert, 1970). Absorption after oral loading of NH_{4+} is similarly complete (Furst et al, 1969).

Ammonium ion absorbed from the gastrointestinal tract travels via the hepatic portal vein directly to the liver, where in healthy individuals, most of it is converted to urea and glutamine. It can be rapidly converted to glutamine in the brain and other tissues as well (Takagaki et al 1961; Warren and Schenker 1964). Nitrogen is released from glutamine within tissue cells and used for protein synthesis as needed (Duder and Handler 1958, Furst et al 1969, Richards et al 1975, Vitti et al 1964). Ingestion of ammonium salts leads to almost complete conversion of ammonium ion into urea in the liver, whereas exposure by other routes may lead to its metabolism in body tissues to glutamine or tissue protein (Furst et al 1969, Vitti et al 1964).

DHHS notes that researchers Duda and Handler (1958) administered 0.03 mg per kg body weight of 15N-ammonium acetate intravenously to rats and noted that 90% was converted to glutamine and urea within 30 minutes, with glutamine being the major early product.[24] Another finding suggests that urea synthesis and glutamine synthesis occur simultaneously within minutes after injection, and that glutamine-amide-N is gradually transferred to the urea cycle 15 to 60 minutes following dosing

[22] [22] *Public Health Statement – Ammonia, CAS#: 7664-41-7*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), September 2004..

[23] *Toxicological Profile for Ammonia*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), September, 2004.

[24] *Toxicological Profile for Ammonia*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), September, 2004.

5. Maintains the acid base balance in your body (continued)

A paper sponsored by the United Nations and other world bodies makes similar points. The ammonia fixed in glutamine may eventually end up in amino acids, purines, pyrimidines or other nitrogen-containing compounds, it says.[25] Ingested ammonium chloride or endogenous ammonia is absorbed into the portal vein and converted in the liver to urea. Ammonia-nitrogen is central in nitrogen metabolism and therefore becomes incorporated in all proteins and nitrogen-containing compounds in the course of metabolic turnover. Some nitrogen derived from absorbed ammonia is incorporated in amino acids and proteins, says the paper.[26]

Ammonia is important for normal animal acid/base balance, says the UN paper.[27] After formation of ammonium from glutamine, a-ketogluterate may be degraded to produce two molecules of bicarbonate, which are then available as buffers for dietary acids.

Ammonium is secreted in the urine resulting in net acid loss, says the paper.[28] Ammonia may itself diffuse across the renal tubules, combine with a hydrogen ion and thus allow for further acid excretion, it says.

Food sources of glutamine include beef and chicken, says a paper by the George Mateljan Foundation.[29] "Glutamine is best known for its ability to serve as a source of fuel for the cells that line the gastrointestinal tract," it says.

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[25] Ammonia (EHC 54), International Programme on Chemical Safety, Environmental Health Criteria 54, published under the joint sponsorship of the United Nations Environmental Programme, the International Labor Organization and the World Health Organization, 1986.

[26] Ammonia (EHC 54), International Programme on Chemical Safety, Environmental Health Criteria 54, published under the joint sponsorship of the United Nations Environmental Programme, the International Labor Organization and the World Health Organization, 1986..

[27] Ammonia (EHC 54), International Programme on Chemical Safety, Environmental Health Criteria 54, published under the joint sponsorship of the United Nations Environmental Programme, the International Labor Organization and the World Health Organization, 1986..

[28] Ammonia (EHC 54), International Programme on Chemical Safety, Environmental Health Criteria 54, published under the joint sponsorship of the United Nations Environmental Programme, the International Labor Organization and the World Health Organization, 1986..

[29] *The World's Healthiest Foods,* on www.whfoods.org, by the George Mateljan Foundation.

5. Maintains the acid base balance in your body (continued)

"More specifically, glutamine is the preferred fuel source for cells lining the small intestine. By nourishing these cells, glutamine helps maintain the health and integrity of the gastrointestinal tract. A healthy tract is vital to preserving overall well being, as the lining of the tract serves as a first line of defense against disease-causing microorganisms and also minimizes the absorption of potentially allergenic molecules. Glutamine also serves as a source of fuel for muscle and immune cells," it says.

In addition, glutamine plays a role in maintaining the body's proper acid-base balance, says the George Mateljan Foundation. "Glutamine is synthesized from glutamate and ammonia. Ammonia is a toxic waster compound with a high pH value, meaning that it is basic (as opposed to acidic). When ammonia levels are elevated, the body clears ammonia form the bloods by synthesizing glutamine. If the blood is too acidic (pH too low), the body can break down glutamine into glutamate and ammonia to increase the pH of the blood."[30]

"Glutamine also serves as a precursor to the antioxidant glutathione, participates in glycogen synthesis (the storage form of carbohydrates), and provides nitrogen compounds for the manufacture of nucleotides, which are used to make DNA and RNA."

The foundation emphasizes the importance of glutamine by noting that muscle and blood concentrations of glutamine are rapidly depleted when the body is confronted with any type of physical stress. For example, high-intensity exercise, injury, surgery, burns, infections and malnutrition cause the body to use up its store of glutamine. During these stressful times, the body is unable to synthesize glutamine fast enough to meet its needs for this amino acid. Consequently, people under physical stress may be at risk for glutamine deficiency, it says.[31]

[30] *The World's Healthiest Foods*, on www.whfoods.org, by the George Mateljan Foundation..

[31] *The World's Healthiest Foods*, on www.whfoods.org, by the George Mateljan Foundation.

1. *The Dynamics of Ammonia Metabolism in Man*, by Alan H. Lockwood, Joseph M. McDonald, Robert E. Reiman, Alan S. Gelbard, John S. Laughlin, Thomas E. Duffy and Fred Plum, Departments of Neurology and Biochemistry, Cornell University Medical Center, and Biophysics Laboratory, Memorial Sloan-Kettering Center, New York, as published in The American Society for Clinical Investigation, Volume 63, March 1979, 449-460.

   Web Link: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=371973

2. *Ammonia Metabolism in the Gut*, by W. H. J. Summerskill, D.M., and Enrique Wolpert, M.D., The American Journal of Clinical Nutrition, Vol. 23, No. 5, May 1970, pp 633-639.

   Web Link: http://www.ajcn.org/cgi/reprint/23/5/633

3. *The World's Healthiest Foods*, by the George Mateljan Foundation.

   Web Link: http://www.whfoods.com/genpage.php?tname=nutrient&dbid=122

4. *Out Of Thin Air*, authored by David W. Wolfe, Natural History, September 2001

   Web Link: http://findarticles.com/p/articles/mi_m1134/is_7_110/ai_78334672

5. *Wikipedia* – Online Encyclopedia; Ammonia

   Web Link: http://en.wikipedia.org/wiki/Ammonia

6. *Public Health Statement – Ammonia, CAS#: 7664-41-7*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), September 2004.

   Web Link: http://www.atsdr.cdc.gov/toxprofiles/tp126.html

7. *Toxicological Profile for Ammonia*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), 1991

   Web Links: http://findarticles.com/p/articles/mi_m1134/is_7_110/ai_78334672

8. Ammonia (EHC 54), International Programme on Chemical Safety, Environmental Health Criteria 54, published under the joint sponsorship of the United Nations Environmental Programme, the International Labor Organization and the World Health Organization, 1986

   Web Link: http://www.inchem.org/documents/ehc/ehc/ehc54.htm

9. *Toxicological Profile for Ammonia*, published by the U.S. Department of Health and Human Services, Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), September, 2004.

   Web Link: http://www.atsdr.cdc.gov/toxprofiles/phs126.html