
Ammonia

It is not considered necessary to establish a maximum acceptable concentration for ammonia in drinking water. Ammonia is produced in the body and is efficiently processed by enzymes in healthy individuals. As well, there seems to be little risk from ammonia in drinking water at the low levels normally encountered.

General

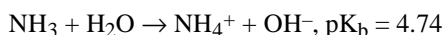
Ammonia (NH₃) is a colourless, alkaline gas at ambient temperature and pressure, with a distinct pungent odour.^(1,2) Produced naturally by the biological degradation of nitrogenous matter (e.g., amino acids) that is present in organic wastes or soils,^(1,3) ammonia provides an essential link in the “nitrogen cycle” of nature.⁽⁴⁾

Ammonia is produced commercially by a catalysed reaction between nitrogen and hydrogen and by its recovery during the isolation of coal gas.⁽¹⁾ It is used in the manufacture of chemical products such as fertilizers, explosives, nitric acid and plastics and in refrigeration plants and petroleum refineries.^(5,6)

In 1984, Canada used 230 420 t of ammonium phosphate (fertilizer grade), 20 157 t of ammonium sulphate (fertilizer grade), 77 813 t of ammonium nitrate and 11 583 t of anhydrous ammonia.⁽⁷⁾ In the first quarter of 1986, Canada produced 946 609 t of anhydrous ammonia, 263 071 t of ammonium nitrate and 365 465 t of ammonium phosphate.⁽⁸⁾ Canada also imports fertilizers in the form of ammonium phosphate and ammonium sulphate.⁽⁹⁾

Occurrence

Ammonia is very soluble in water; approximately 90 g dissolve in 100 mL of distilled water at 0°C.⁽¹⁰⁾ In solution, some of the ammonia reacts with the water, resulting in the following equilibrium⁽¹⁾:



For the purpose of this review, reference to the ammonia content of water should be taken to mean the sum total of ammonia and ammonium ion content. In the pH range of most natural waters, ammonia nitrogen will exist principally as NH₄⁺.⁽¹⁾

Ammonia is present in most waters as a result of the biological degradation of nitrogenous organic matter, although it may also reach groundwater and surface waters from industrial waste discharges.⁽²⁾ The concentration of ammonia in Canadian surface waters in a 1980–1981 survey ranged from <0.001 to 0.587 mg/L.⁽¹¹⁾ In a survey of 19 public water supplies conducted in Ontario in 1985 and 1986, it was found that the mean level of ammonia (as nitrogen) in untreated water was 0.20 mg/L, with a range of <0.02–0.65 mg/L. After treatment, the mean level was 0.17 mg/L (range <0.02–0.40 mg/L), whereas the mean level in the distribution system was 0.15 mg/L (range <0.02–0.44 mg/L).⁽¹²⁾

Most atmospheric ammonia is produced by natural biological processes, whereas additional quantities are released to the atmosphere as a result of the distillation and combustion of coal and the biological degradation of manure.^(3,13–15) In Canada, during 1980, natural and anthropogenic emissions of ammonia contributed 505 623 and 204 432 t of ammonia, respectively, to the atmosphere. Ninety percent of the natural emissions originated from biological litter, a further 7% from animal waste and most of the rest from forest fires. Of the anthropogenic emissions, 56% originated from animal waste associated with feedlots, whereas handling and storage operations at ammonia plants contributed 26%. Urea production and direct application of ammonia to the soil both accounted for a further 5% each, whereas cigarette smoking contributed 3% to the total anthropogenic emissions.⁽¹⁶⁾

Canadian data on levels of ammonia in urban air are sparse; however, a study of the chemical composition of particulate matter and aerosols over Edmonton in the winter of 1978 and the spring and summer of 1979 showed that the mean ammonium ion concentration remained constant at 0.8 µg/m³,⁽¹⁷⁾ compared with the U.S. national estimated average of 14 µg/m³.⁽¹⁰⁾ The global average ammonia concentration in the atmosphere, resulting primarily from natural sources, has been estimated to be 4.2 µg/m³.⁽¹⁰⁾

In soils, the concentration of ammonia is high and depends on the species of bacteria present, the quantity of plant life, soil characteristics and general climatic conditions.

Ammonia is present in a limited number of foodstuffs, such as cheeses, aged or stored meats and stored vegetables. The ammonia is formed as the result of fermentation and autolytic deamination and deamidation.⁽¹⁸⁾ Ammonium salts are widely used in baked goods, candies, gelatin, fats and oils, jellies, cheeses, processed fruits and beverages.

Canadian Exposure

Estimates of the daily dietary intake of ammonia and ammonium salts for Canadians have not been made. Based on a U.S. estimate, the average daily ammonia intake from six different ammonium salt additives in food has been calculated to be 18 mg.⁽¹⁹⁾

Assuming a daily water consumption of 1.5 L and an average ammonia concentration of 0.2 mg/L (as nitrogen) — approximated from the mean level of ammonia measured in treated water in the Ontario study⁽¹²⁾ — the average daily intake of ammonia (as nitrogen) from drinking water would be about 0.3 mg per person.

Assuming that the concentration of atmospheric ammonia in Canada approaches the U.S. estimated urban level of 0.014 mg/m³⁽¹⁰⁾ and that 20 m³ of air are inhaled, the daily exposure to ammonia via this route would also be approximately 0.3 mg.

Analytical Methods and Treatment Technology

Ammonia in water can be determined quantitatively by several methods, including titration (1–25 mg/L), indophenol reaction (10–2000 µg/L), potentiometry (0.05–1400 mg/L) and reaction with Nessler's reagent (1–25 mg/L,⁽¹⁹⁾ or as low as 20 µg/L as ammonia nitrogen under optimum conditions⁽²⁰⁾).

Ammonia removal during drinking water treatment is not usually required. Ammonia removal by air stripping is a fairly common process, particularly in wastewater treatment. Adsorption and demineralization processes may also be effective for ammonia removal. If chlorination is used in water treatment, any ammonia will combine with the chlorine to form chloramines. As well, pH adjustment can be used to affect the form of ammonia in the water.⁽²¹⁾

Health Considerations

Bacterial activity in the intestine may increase human exposure to ammonia.⁽²²⁾ Deamination reactions liberate ammonia from dietary proteins as well as from proteins secreted into the intestine or released from the intestine as a result of gastrointestinal bleeding. Hydrolysis reactions, catalysed by the bacterial enzyme urease, can split urea into ammonia and carbon dioxide.^(23,24) It has been suggested that one-quarter of all urea produced by the liver is hydrolysed in the

intestine and that the ammonia produced is reabsorbed and transported to the liver for resynthesis into urea.

Absorption, Distribution and Excretion

The absorption of ammonia occurs almost entirely in the ileal segment of the intestine.⁽²⁵⁾ It has been shown that whereas absorption of free ammonia from the intestine is rapid,⁽²⁶⁾ the cell membrane is relatively impermeable to the ammonium ion.⁽²⁷⁾

The levels of ammonia in the blood are usually low (10–70 µg nitrogen/100 mL), although reported values reflect to some extent the sampling and analytical techniques used.⁽²⁸⁾

Ammonia is primarily excreted by the kidney in the form of urea. The urine may also contain considerable amounts of free ammonia, normally between 500 and 1200 mg in a 24-hour period,⁽²⁹⁾ although values may range between 0 and 2000 mg.⁽³⁰⁾ Most of the free urinary ammonia is produced in the kidneys by deamination of amino acids, particularly glutamine, and utilized for hydrogen ion excretion as part of the pH regulatory system.

Peripheral tissues may also remove ammonia from the blood by metabolically incorporating it into glutamine.⁽³¹⁾ Glutamine is freely permeable and may transfer ammonia to other tissues for nitrogen transfer reactions or for metabolic degradation via the urea cycle.⁽³⁰⁾

Toxic Effects

Despite high-protein diets and the consequent ammonia release by the intestinal flora followed by rapid ammonia absorption, fast and efficient enzyme systems maintain low tissue levels of ammonia.^(28,30) These enzymes, primarily glutamate dehydrogenase, glutamine synthase and carbamoyl phosphate synthetase, seem so efficient that most reports of acute toxicity focus on the corrosive alkali nature of ammonia towards eyes, skin and lungs, rather than on internal tissue or metabolic effects.⁽³⁰⁾ Substrates of the urea cycle, such as arginine, citrulline and ornithine, are reported to act as protective agents against ammonia toxicity, possibly by stimulating urea formation.⁽³⁰⁾

Ingestion of massive doses of ammonium chloride by human adults (52–105 g over three days) resulted in headache, insomnia, nausea, diarrhoea and a failure in glucose tolerance. A dose of 6–8 g daily for 6–9 days resulted in increased urinary output of renal ammonia and urinary magnesium, calcium and phosphate.⁽³²⁾

Generally, a large intravenous dose of ammonia produces immediate hyperventilation and clonic convulsions, followed by either fatal tonic extensor convulsions or gradual onset of coma. If the comatose animals do not enter tonic convulsion, a rapid and complete recovery is common.⁽³⁰⁾ Intraperitoneal injections produce the same results, but the onset of

reactions is delayed. Hypoxia may increase ammonia toxicity in mice.⁽³³⁾ Hyperthermia may also increase toxicity, whereas hypothermia has been suggested as a treatment for hepatic coma.⁽³⁴⁾

There is some evidence that cardiac tissue may be a target organ for ammonia.^(35,36) Most evidence points to ammonia interference with energy metabolism in the brain either by depletion of the Krebs cycle intermediates or by reduction of ATP or NADH and subsequent effects on neurotransmitter availability.⁽³⁰⁾

More pertinent to ammonia in drinking water are the metabolic toxicity studies obtained from individuals with impaired ammonia handling — for example, hepatic insufficiency or congenital enzyme disorders.⁽³⁰⁾

Other Considerations

Ammonia in drinking water may increase the chlorine demand, which may lead to a “break-point” chlorination phenomenon.⁽³⁷⁾ Ammonia and ammonium compounds may be added to water in order to lower trihalomethane production.⁽³⁸⁾

Ammonia occurs naturally in drinking water and may stratify in impounded water.⁽³⁰⁾ Ammonia should be considered as a potential source of nitrates (see document on nitrate/nitrite).

Estimated taste and odour thresholds for ammonia are 35 mg/L (as NH₃) and 35 mg/m³, respectively. Sensitive individuals may detect concentrations an order of magnitude lower.⁽¹⁹⁾ A water odour threshold concentration as low as 1.5 mg/L has also been reported.⁽³⁹⁾

Conclusion

Ammonia is produced in the body and is efficiently processed by enzymes in healthy individuals. There seems to be little risk from ammonia in drinking water at the levels normally encountered.

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