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GUIDES FOR SHORT-TERM EXPOSURES OF THE PUBLIC TO AIR POLLUTANTS. IV. GUIDE FOR AMMONIA

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Guides for Short-Term Exposures of the Public to Air Pollutants

IV. Guide for Ammonia

by

The Committee on Toxicology

of the

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INTRODUCTION

The Environmental Protection Agency has focused its initial concerns on long-term exposures of the public to air pollutants. In addition to the long-term levels there are occasional circumstances wherein the public may be exposed briefly to relatively high concentrations. For example, batch-process techniques in industries may result in pulses of effluent. The testing and launching of rockets releases exhaust products. Rapidly changing meteorological conditions may result in short periods of locally high concentration of stack effluents. Accidental releases of chemicals sometimes occur in industrial areas or during transport, and may lead to exposure of the public.

Recognizing that these occasional peak conditions in ambient exposures of the public do occur, the Environmental Protection Agency has requested the assistance of the Committee on Toxicology of the National Academy of Sciences-National Research Council in providing Guides for Short-Term Exposure Limits for Air Pollutants.

In preparing these Guides, the Committee utilized the criteria described in the NAS-NRC document entitled "Basis for Establishing Guides for Short-Term Exposures of the Public to Air Pollutants" (21). Primary consideration was given to literature dealing with single or intermittent brief exposures to the contaminant in question, in this case ammonia.

Ammonia

Introduction

Ammonia, a colorless gas at ambient temperatures and pressures, has the following characteristics:

Molecular weight: 17.03
Boiling point: -33° C
Solubility: 90 g in 100 ml H_2O (at 0° C)
Explosive limits: 16 - 25% by volume in air
Vapor density (air=1): 0.597 (STP)
Specific gravity of liquid NH_3: approximately 0.6
pH of a 1% solution in H_2O: approximately 11.7
Odor threshold: 5-53 ppm

Ammonium hydroxide, a 28% solution of ammonia in water, and "household ammonia," normally a 10% aqueous solution, are two common preparations of this gas.

Ammonia is a naturally occurring substance, the result of protein metabolism in living organisms. It is readily absorbed. Ruminants use the ammonia to make amino acids (36) but in man virtually all is immediately reconverted to urea in the liver. Individuals with severe liver disease may fail to detoxify the ammonia and may manifest derangements of central nervous system functions (37). Ammonia is also formed from glutamate by the kidney (35) and in this organ is an important component of the acid, base, electrolyte balancing system. In normal man the mean blood level (measured as N) is 0.08 mg% (34).

The global average of ammonia in the atmosphere has been estimated to be 6 parts per billion of air (ppb)* resulting primarily from natural sources (5). Sawicki (6) estimates the average concentration in urban air to be about 20 ppb. The annual U.S. production (synthetic) in 1971 has been reported to be 27.4 billion pounds.

* At 25° C and 760 mm Hg 1 ppm $NH_3 \cong 0.7\ mg/m^3$.

Effects on Animals

Henderson and Haggard (1) classify ammonia as a primary irritant. Silver and McGrath (2) exposed white mice to high concentrations of ammonia for 10-minute periods and reported the LC_{50} to be 7,060 mg/m^3 (~10,200 ppm) with 93% of the deaths occurring during exposure. During exposure the mice exhibited great excitement, their eyes were closed, and within one minute they were gasping. Convulsions and deaths began to occur after the fifth minute. The report does not include a description of pathological changes.

Rats exposed to approximately 100 ppm ammonia (70 mg/m^3) for 5 hrs/day, 5 days/week for a total of 60 days showed no difference between the rate of their ciliary activity and that in control animals. However, histological changes in the epithelium of the trachea of the exposed animals were greater than in the controls (11).

Coon et al. (4) tested rats, guinea pigs, rabbits, monkeys, and dogs with continuous (65 to 114 days) or repeated (8 hrs/day x 5 days/week for 6 weeks) exposures to ammonia. Repeated exposure at 155 mg/m^3 (223 ppm) produced no adverse effects. After repeated exposures at 770 mg/m^3 (1100 ppm) the authors reported finding ocular and nasal irritation in rabbits and dogs and inflammatory changes in the lungs of rats and guinea pigs.

Continuous exposure at 40 mg/m^3 (58 ppm) was observed to cause non-specific inflammatory changes in the lungs of the experimental animals (114 days of exposure) and, at 127 mg/m^3 (183 ppm) and 262 mg/m^3 (377 ppm), similar changes were reported in both the lungs and kidneys (90 days of exposure). Continuous exposure at levels of 445 mg/m^3 (665 ppm) and 470 mg/m^3 (677 ppm) for 65 and 90 days respectively caused 87-98% mortality in exposed rats and marked eye irritation in rabbits and dogs.

Weatherby (8) exposed male guinea pigs to ammonia at a concentration of 170 ppm (140-200 ppm) for 6 hrs/day, 5 days/week for up to 18 weeks and examined the animals at 6-week intervals. Animals sacrificed after 6 and 12 weeks showed no abnormalities that could be attributed to ammonia. Examination of the animals exposed for 18 weeks reportedly revealed considerable congestion of spleens, livers, and kidneys and early degenerative changes in the adrenal glands. It is interesting to note that no changes suggestive of chronic intoxication were observed in the heart, lungs, stomach, or small intestine of the experimental animals.

Because of its high solubility in water, ammonia would be expected to act as an irritant primarily on the upper respiratory passages, being absorbed by the moist membranes lining these passages. Absorption of ammonia by the upper respiratory tract may prevent irritation of the deeper lung structures. Boyd and co-workers (7) demonstrated such a "Naso-Bucco-Pharyngeal Filter" in rabbits. The authors also concluded that the upper respiratory tract is more resistant to the action of ammonia than is the brochiolar-alveolar structure.

Cralley (3) examined the effects of ammonia on mucociliary activity of sections of excised rabbit trachea. He observed that 500 ppm NH_3 for five minutes or 400 ppm for 10 minutes caused irreversible cessation of ciliary activity.

Dalhamn and co-workers (9,10,11), in a series of experiments, examined the effects and absorption of ammonia on the ciliated epithelium and upper respiratory tract of rabbits and rats. Ammonia concentrations of 500 ppm caused cessation of ciliary activity on excised rabbit trachea in 5 to15 minutes (9). At concentrations below 260 ppm, there was no discernible effect on ciliary activity through 20 minutes of exposure (10). These authors concluded that "a concentration of about 100 ppm ammonia seemed to be the critical level influencing ciliary beating, and the con-concentration of NH_3 in the air entering the nose should be about 2000 ppm to produce the requisite 100 ppm in the trachea."

It is interesting to note that exposure of rats to about 100 ppm ammonia along with carbon particles (3.5 mg/m^3) for 5 hrs/day, 5 days/week for 60 days resulted in a significant decrease in ciliary activity as well as more pronounced histological changes in the tracheae of the exposed animals. Carbon particles alone at concentrations of 7 mg/m^3, did not cause any significant changes in the ciliary activity or in the histological appearance of the tracheal epithelium (11). Absorption of NH_3 to the carbon particles may have resulted in an increased carriage of NH_3 into the trachea.

Effects on Humans

The odor threshold for ammonia has been variously reported as low as 5 ppm and as high as 53 ppm (15,17); recent evidence cited in the 1971 TLV documentation (18) indicates that the odor threshold is in the area of 5 ppm. Another unpublished inquiry supports this lower level (16).

The physiological effects of ammonia on humans appears to be similar to that observed in experimental animals. Irritation of the mucous membranes of the upper respiratory tract becomes noticeable at about 100 ppm and concentrations above 400 ppm may destroy mucous surfaces upon prolonged contact (duration of exposure not given) (12). Weatherby (8) states that 5 or 6 members of his staff inhaled chamber exhaust air containing 140-200 ppm ammonia and all were of the opinion that no person would remain in such an atmosphere voluntarily for any appreciable period of time because of the disagreeable odor and respiratory distress. However, Silverman and co-workers (19) report that subjects voluntarily inhaled 500 ppm ammonia for 30 minutes. Evidently concentrations between 140 and 500 ppm are irritating although tolerable for at least 30 minutes. Concentrations in excess of 2500 ppm are reported to be dangerous for as little as 1/2 hour (12) although fatal inhalation of ammonia would be expected only when the victim is unable to escape from the contaminated atmosphere. Death is usually from pulmonary edema (12-14).

Silverman and co-workers (19) found that the retention of ammonia in the respiratory passages of humans was considerably less than that reported by Landahl and Herrmann (20) when exposure time was increased up to 30 minutes. They exposed seven human volunteers to ammonia at 500 ppm (350 mg/m^3) and found that the average retention of ammonia was 20% with time to equilibrium ranging from 10 to 27 minutes. The symptoms of the subjects were reported to be nasal dryness and irritation, excessive lacrimation in two subjects and elevation of the minute respiratory volume 50% to 250% over control values. No significant changes in nitrogen metabolism were observed in response to the ammonia exposures.

Long industrial experience indicates that no permanent injury occurs from exposure to NH_3 throughout a working lifetime at levels below those that cause intolerable acute effects.

<u>Guide Values for Short-Term Limits</u>

Short-term public exposures are those occurring at predictable times and arising from single or, occasionally, repeated events. Since the exposure can be predicted there is no justification for submitting the public to any appreciable risk (21). The concentrations given below may be odorous, but are expected to be tolerable. They are considered to be below the level of irritation and well below the levels that might be expected to cause injury.

<u>Short-Term Public Limits (STPL's)</u>

10 min	20 ppm (ceiling)
30 min	10 ppm (ceiling)
60 min	10 ppm (ceiling)
5 hrs/day, 3-4 days/mo	5 ppm (Time-weighted averages with excursions above average not to exceed "ceiling" limits)

Many people find the odor of ammonia objectionable and any concentration above their odor threshold may be expected to produce complaints from these individuals regardless of how short the exposure.

Public Emergency Limits (PEL's)

Public emergency limits apply to situations in which pollutants escape in an uncontrolled manner at unpredicted times and places as the result of accidents such as damage to transportation equipment or fire in a chemical-storage facility. Although the STPL's require that there be no adverse effects, the PEL's recognize the possibility of some serious discomfort, provided that the effect is reversible and that no serious sequelae result from it. The concentrations in the following PEL's are considered to present a strong odor with possible lacrimation and irritation of the upper respiratory tract (nose and throat), but no incapacitation or prevention of self-rescue.

Public Emergency Limits (PEL's)

10 min	100 ppm
30 min	75 ppm
60 min	50 ppm

The preceding limits are proposed on the basis of studies examining the effects of NH_3 inhalation on healthy animals and humans. It is suggested that appropriate research be done to determine the effects of NH_3 inhalation on persons having pre-existing pulmonary disease in order to determine whether such persons are more susceptible to these effects.

In recommending the limits the Committee on Toxicology assumed that NH_3 was the only contaminant to which the public would be exposed during any single episode. Mixed exposures to pollutants causing synergistic effects with NH_3 such as those observed with NH_3 and carbon particles (11) might well require more conservative exposure limits.

Effects of Ammonia on Vegetation

The effects of ammonia on plants have not received a great deal of study possibly because continuous emission from industrial sources is not sufficiently high to produce acute injury symptoms. Reports of field injury from gaseous ammonia can be expected as anhydrous ammonia becomes more and more popular as a fertilizer.

Buckwheat, coleus, sunflower, and tomato foliage have reportedly been injured upon exposure to 40 ppm NH_3 for 1 hour. Slight marginal injury has been observed in these plants after a 4-hr exposure to 16.6 ppm NH_3 (23).

Benedict and Breen (24) used weeds as a means of evaluating potential vegetation damage due to a number of air pollutants. They found that a 4-hr exposure to an ammonia level of 12 ppm produced some leaf marking in most of 10 varieties of weeds that were tested. Sunflower and mustard were the most susceptible having 30% and 22% of the leaf area "marked." Dandelion, pigweed, and chickweed were observed to be the least susceptible. Little effect was observed on the plants after a 4-hr exposure at 3 ppm. Drying the soil in which the plants were growing before exposing them to ammonia resulted in decreased marking of the leaves. Middle-aged leaves (those that had been at full size for about one week) appeared to be the most susceptible to the ammonia, with younger leaves rarely being marked.

Hutchinson et al. (25) monitored the ammonia levels in growth chambers containing single seedlings of cotton, corn, soybean, or sunflower, and reported that these seedlings absorb significant quantities of NH_3 even at low atmospheric levels (34-63 ppb). They conclude that the atmospheric levels might satisfy up to 10% of the total nitrogen requirement of the plants.

Porter et al. (26) using levels of 1, 10, and 20 ppm ^{15}N-labeled ammonia, reported that up to 43% of atmospheric ammonia was absorbed and rapidly metabolized to amino acids and protein by corn seedlings over a 24-hr exposure period. The authors observed no visible damage to the plants after a 24-hr exposure at these levels.

Ammonia at very high concentrations (15,000 - 45,000 ppm) for brief periods of time (0.5 sec) has been used as a defoliant for cotton crops (27).

Effects on Materials

Ammonia, in the presence of water or water vapor, will attack copper, silver, zinc, and all their alloys. Galvanized surfaces as well as aluminum and its alloys may also be corroded by ammonia in the presence of moisture. Iron and steel will not react readily with either dry or moist ammonia (31).

Contact of ammonia with certain other chemicals including mercury, chlorine, iodine, bromine, calcium, silver oxide, or hypochlorite can form explosive compounds (31).

An in-depth discussion concerning the corrosivity of metals and alloys is beyond the scope of this guide. The corrosive potential of ammonia on a number of metals is given in Metals Handbook (32).

Analytical Methods

Although a number of methods are available for measuring NH_3 in the air, many of them are only semi-quantitative and serve only as indicators of the presence of NH_3. One such method is the use of moist litmus paper, which, it is claimed, will turn blue in one second at 100 ppm NH_3 and in 6.5 seconds at 10 ppm (28).

Absorption of the NH_3 in a standard acid and titration of the excess acid using a standard base is a method generally applicable to NH_3 determination (29).

The most popular method for NH_3 analysis in both air and water is determination with Nessler's reagent (28, 29, 30). Sensitivity of 3 ppm in a 50-liter air sample is reported.

A recently developed method for determination of NH_3 is the "ammonia electrode," claimed to have a sensitivity down to 20 ppb. The method is based on the conversion of NH_3 in solutions to NH_4^+ with the production of an OH^- which is "sensed" by means of a membrane electrode. The response time for the instrument is reported to be less than one minute (33).

References

1. Henderson, Y. and Haggard, H. W. Noxious Gases and the Principles of Respiration Influencing their Action. New York. Reinhold Publ. Co. 1943. (p. 124-125).

2. Silver, S. D. and McGrath, F. P. A comparison of acute toxicities of ethylene imine and ammonia to mice. J. Ind. Hyg. Tox. 30:7-9 1948.

3. Cralley, L. V. The effects of irritant gases upon the rate of ciliary activity. J. Ind. Hyg. Tox. 24:193-198 1942.

4. Coon, R. A., Jones, R. A., Jenkins, L. J., Jr., and Siegel, J. Animal inhalation studies on ammonia, ethylene glycol, formaldehyde, dimethylamine, and ethanol. Toxicol. Appl. Pharmacol. 16: 646-655 May 1970.

5. Robinson, E. and Robbins, R. C. Gaseous nitrogen compound pollutants from urban and natural sources. JAPCA 20:(5) 303-306 1970.

6. Sawicki, E. Airborn carcinogens and allied compounds. Arch. Environ. Health 14:46-53, 1967.

7. Boyd, E. M., Maclachlan, M. L., and Perry, W. F. Experimental ammonia gas poisoning in rabbits and cats. J. Ind. Hyg. Tox. 26: 29-34, 1944.

8. Weatherby, J. H. Chronic toxicity of ammonia fumes by inhalation. Proceedings Soc. Exper. Biology and Medicine 81:300-301, 1952.

9. Dalhamn, T. and Sjöholm, J. Studies on SO_2, NO_2, and NH_3: Effects on ciliary activity in rabbit trachea of single in vitro exposure and resorption in rabbit nasal cavity, Acta. physiol. scand. 58:287-291 1963.

10. Dalhamn, T., Effects of ammonia alone and combined with carbon particles on ciliary activity in the rabbit trachea in vivo with studies of the absorption capacity of the nasal cavity. Intern. J. of Air and Water Pollution 7:531-539 1963.

11. Dalhamn, T. and Reid, L. Ciliary activity and histologic observations in the trachea after exposure to ammonia and carbon particles. IN: Inhaled Particles and Vapors II. Davies, ed., Pergamon Press, 1967.

12. Patty, F.A., ed. Industrial Hygiene and Toxicology, Vol. II, 2nd ed. New York. Interscience Publs. 1963. (p. 862)

13. Fairhall, L. T. Industrial Toxicology, 2nd ed. Baltimore, Williams and Wilkins Co. 1957 (p. 14).

14. Caplin, M. Ammonia-gas poisoning. Forty-seven cases in a London shelter. Lancet, 241:95-96, 1941.

15. Flury, F. and Zernik, F: Schadliche Gase. Berlin. Verlag von Julius Springer. 1931. (p. 152).

16. Smyth, H. Jr. personal communication.

17. Leonardos, G., Kendall, D. and Barnard, N. J. Odor threshold determination of 53 odorant chemicals. Presented at 61st Annual Meeting, Air Pollution Control Assoc., St. Paul. June 23-27, 1968. Paper No. 68-13.

18. Am. Conf. Govern. Ind. Hyg. Documentation of Threshold Limit Values for Substances in Workroom Air. Cincinnati, Ohio. Third Ed. 1971.

19. Silverman, L., Whittenberger, J. and Muller, J. Physiological response of man to ammonia in low concentrations. J. Ind. Hyg. Tox. 31:74-78, 1949.

20. Landahl, H. D. and Herrmann, R. G. Retention of vapors and gases in the human nose and lung. Arch. Ind. Hyg. 1:36-45 1950.

21. National Academy of Sciences-National Research Council, Committee on Toxicology. Basis for establishing guides for short-term exposures of the public to air pollutants. June 1971.

22. Dalhamn, T., Mucous flow and ciliary activity in the trachea of healthy rats and rats exposed to respiratory irritant gases. Acta Physiol. Scand. Suppl. 123, pp. 1-161 (1956).

23. Heck, W. W., Daines, R. H., and Hindawi, I. J. "Other phytotoxic pollutants." IN: Jacobson, J. S. and Hill, A. C., editors. Recognition of Air Pollution Injury to Vegetation: A Pictorial Atlas. Air Pollution Control Association Informative Report No. 1. TR-7 Agricultural Committee. 1970. p. F-1-F-24.

24. Benedict, H. M. and Breen, W. H. The use of weeds as a means of evaluating vegetation damaged caused by air pollution. Proc. 3rd Natl. Air Pollution Symp. Pasadena, Calif. 1955. p. 177-190.

25. Hutchinson, G. L., Millington, R. J., and Peters, D. B. Atmospheric ammonia - Absorption by plant leaves. Science 175:771-772. February 18, 1972.

26. Porter, L. K., Viets, F. G., Jr., and Hutchinson, G. L. Air Containing nitrogen-15 ammonia: Foliar absorption by corn seedlings. Science 175:759-761. February 18, 1972.

27. Fisher, J. B., and Cazaly, G. W. Defoliation of cotton plants with ammonia. U. S. Patent No. 3,095,298. June 25, 1963.

28. Hygienic Guide Series - Anhydrous ammonia. Am. Ind. Hyg. Assoc. J. 32:139-142 1971.

29. Elkins, H. B. The Chemistry of Industrial Toxicology. New York. John Wiley and Sons, Inc. 1959.

30. ASTM Standards: Industrial Water; Atmospheric Analysis. Part 23. 1965. American Society for Testing and Materials, Philadelphia p. 326-331.

31. Manufacturing Chem. Assoc. Data Sheets SD8 (anhydrous ammonia, 1960) and SD13 (aqua ammonia, 1947). Lyman, T. (editor).

32. Lyman, T. Metals Handbook. Vol. I. Properties and Selection of Metals. Am. Soc. Metals, Metals Park, Novelty, Ohio. 8th ed.

33. Orion Res., Inc. Data Sheet Form DS95-10/1711. 1971.

34. Diem, K., editor. Documenta Geigy. Scientific Tables. 6th ed. Geigy Pharmaceuticals. Ardsley, New York. 1962. (p. 558)

35. Lowenstein, J. M. Ammonia production in muscle and other tissues: the purine nucleotide cycle. Physiol. Reviews 52:382-414 April 1972.

36. Chalupa, W. Metabolic aspects of nonprotein nitrogen utilization in ruminant animals. Fed. Proc. 31:1152-1164 May-June 1972.

37. Visek, W. J. Effects of urea hydrolysis on cell life-span and metabolism. Fed. Proc. 31:1178-1193 May-June 1972.

END