OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR CAPROLACTAM DUST

INTRODUCTION

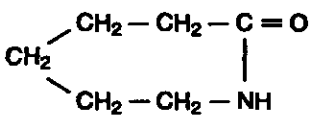
This guideline summarizes pertinent information about caprolactam dust for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_6H_{11}NO$

- **Structure**



- **Synonyms**

Aminocaproic lactam; epsilon-caprolactam; 2-oxohexamethylenimine; 2-ketohexamethylenimine; 2-perhydroazepinone; Akulon; Alkamid; Amilan; ATM 2(Nylon); Bonamid; Capran 80; Caprolon B; Capron; Chemlon; Danamid; Durethan BK; Grilon; Itamid; Kaprolit; Maranyl; Miramid; Orgamide; Nylon X 1051; Plaskin 8200; Spencer 401; Tarlon XB; Ultramid; Vidlon

- **Identifiers (For caprolactam)**

1. CAS No.: 105-60-2
2. RTECS No.: CM3675000
3. DOT UN: None
4. DOT label: None

- **Appearance and odor**

Caprolactam dust is a white, crystalline, finely divided particulate that has an unpleasant odor.

CHEMICAL AND PHYSICAL PROPERTIES (For caprolactam)

- **Physical data**

1. Molecular weight: 113.2
2. Boiling point (760 mm Hg): 266.9°C (512.42°F)
3. Specific gravity (water = 1): 1.02 at 75°C (167°F)
4. Vapor density (air = 1 at boiling point of caprolactam dust): 3.9
5. Melting point: 70°C (158°F)
6. Vapor pressure at 20°C (68°F): 0.001 mm Hg
7. Solubility: Soluble in water, benzene, chloroform, chlorinated hydrocarbons, cyclohexene, and petroleum fractions; freely soluble in methanol, ethanol, tetrahydrofurfuryl alcohol, ether, and dimethylformamide

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Education and Information Division

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Moisture, heat, sparks, and open flame

2. Incompatibilities: Contact of caprolactam dust with strong oxidizing agents should be avoided.

3. Hazardous decomposition products: Toxic gases (such as oxides of nitrogen) may be released in a fire involving caprolactam dust.

4. Special precautions: None reported

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to caprolactam; other sources rate caprolactam's fire hazard as slight.

1. Flash point: 125°C (257°F) (open cup)

2. Autoignition temperature: Data not available

3. Flammable limits in air (% by volume): Lower, 1.84; upper, 8.0

4. Extinguishant: Use carbon dioxide, dry chemical, alcohol foam, or water fog to fight fires involving caprolactam dust. Water or foam may cause frothing. Do not use a solid stream of water because the stream will scatter and spread the fire. Water may be used to cool fire-exposed containers.

Fires involving caprolactum dust should be fought upwind from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Firefighters should wear a full set of protective clothing and self-contained breathing apparatus when fighting fires involving caprolactam dust.

EXPOSURE LIMITS

- **OSHA PEL**

The Occupational Safety and Health Administration (OSHA) has not promulgated a permissible exposure limit (PEL) for caprolactam dust [29 CFR 1910.1000, Table Z-1].

- **NIOSH REL**

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 1 mg/m^3 as a TWA for up to a 10-hr workday and a 40-hr workweek and 3 mg/m^3 as a STEL. A STEL is the maximum 15-min concentration to which workers may be exposed during any 15-min period of the working day [NIOSH 1992].

- **ACGIH TLV**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned caprolactam dust a threshold limit value (TLV) of 1 mg/m^3 as a TWA for a normal 8-hr workday and a 40-hr workweek and a STEL of 3 mg/m^3 for periods not to exceed 15 min [ACGIH 1993].

- **Rationale for limits**

The NIOSH limits are based on the risk of convulsions, dermal sensitization, and dermal and respiratory irritation [NIOSH 1992].

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Exposure to caprolactam dust can occur through inhalation and eye or skin contact.

- **Summary of toxicology**

1. *Effects on Animals:* In animals, caprolactam dust is an irritant of the eyes, nose, and skin and a central nervous system depressant. Applied to the eyes of rabbits, 20 mg of this substance caused a moderate degree of irritation; 500 mg of caprolactam applied to the skin of rabbits for 24 hr caused mild skin irritation [NIOSH 1993]. The dermal LD_{50} in rabbits is 1.4 g/kg [NIOSH 1993]. Acutely poisoned animals convulsed and showed other nervous system effects before death [NIOSH 1993]. The oral LD_{50} in rats is 1.2 g/kg; the LC_{50} in the same species is 300 mg/m^3 for 2 hr [NIOSH 1993]. Administered intraperitoneally, caprolactam at doses of 350 to 600 mg/kg caused tremor, convulsions, and a bloody eye discharge [Hathaway et al. 1991]. Guinea pigs tolerated seven daily 7-hr exposures to a concentration of caprolactam ranging from 118 to 261 mg/m^3 without

evidence of adverse effects other than occasional coughing [ACGIH 1991]. Male rats exposed 4 hr/day to a 125 mg/m^3 concentration of caprolactam dust for 2.5 months showed increasing excitability, changes in spermatogenesis, and a decrease in respiratory rate and urinary function [IARC 1986]. Exposure to a 11 mg/m^3 concentration on the same regimen caused no adverse reproductive effects [IARC 1986]. In a 3-generation reproductive study in rats fed caprolactam at a dietary dose of 5,000 or 10,000 ppm, this substance caused dose-related decreases in food consumption and in body weight in dams and pups; at a dietary level of 10,000 ppm, signs of minimal kidney toxicity were seen in males at autopsy, but no reproductive or fetotoxic effects were observed [ACGIH 1991]. A 2-year carcinogenicity bioassay of caprolactam in mice and rats showed negative results [IARC 1986].

2. *Effects on Humans:* In humans, exposure to caprolactam causes eye, skin, and respiratory tract irritation, convulsions, and, in some individuals, dermal sensitization [ACGIH 1991]. Repeated exposure of the skin to the dust of caprolactam causes peeling and fissuring in chronically exposed workers [ACGIH 1991]. Workers exposed to the fumes of caprolactam (condensed from the vapor) at concentrations ranging from 6 to 131 mg/m^3 for 9 months to 13 years reported sensory irritation and dermatitis; however, no caprolactam-related pulmonary effects or signs of systemic toxicity were seen in these workers [ACGIH 1991]. Another study showed that workers repeatedly exposed to caprolactam dust (condensed vapor) generated by the spinning process complained of a bitter taste, nervousness, nose bleeds, productive cough, and dry, split mucous membranes. Some complained of flatulence, heartburn, and a heavy feeling in the stomach [ACGIH 1991]. A group of male workers exposed to several chemicals, including caprolactam dust, showed an increase in sperm abnormalities, and women occupationally exposed to this substance have been reported to have an increased rate of complications during pregnancy; however, confounding exposures and other methodological problems make interpretation of these results difficult [IARC 1986].

- **Signs and symptoms of exposure**

1. *Acute exposure:* Acute exposure to caprolactam dust may cause redness, inflammation, and tearing of the eyes; redness and inflammation of the eyelids; runny nose; scratchy throat; coughing; and redness or blistering of the skin.

2. *Chronic exposure:* Chronic exposure to caprolactam dust may cause dermatitis (fissuring, peeling, and inflammation); some individuals become sensitized to caprolactam and may have an allergic skin reaction (i.e., hives) to this substance on subsequent exposure.

- **Emergency procedures**

WARNING!

Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure:* Irritation may result. ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure:* Irritation may result. ***Immediately and thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure:* Move the victim to fresh air ***immediately***. Have the victim blow his or her nose, or use a soft tissue to remove particulates or residues from the nostrils.

   If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Ingestion exposure:* Take the following steps if caprolactam dust or any material containing it is ingested:

   —Have the victim rinse the contaminated mouth cavity several times with a fluid such as water.

   —Have the victim drink a glass (8 oz) of fluid such as water.

   —Induce vomiting by having the victim touch the back of the throat with a finger until productive vomiting ceases. Do ***not*** give syrup of ipecac because of possible onset of respiratory depression and seizures.

—Do *not* force an unconscious or convulsing person to drink fluid or to vomit.

5. *Rescue:* Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures, the location and proper use of emergency equipment, and procedures for protecting themselves in rescue operations.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve caprolactam dust and may result in worker exposures to this substance:

—Use as a chemical intermediate in the production of nylon-6 fibers and plastics

—Use as a solvent for some high molecular weight polymers

—Use in making coatings, plasticizers, paint vehicles, and synthetic leather

The following methods are effective in controlling worker exposures to caprolactam dust, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to caprolactam dust, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to caprolactam dust at or below the prescribed exposure limit. The health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with diseases of the eyes, skin, and respiratory tract.

- **Periodic medical examinations and biological monitoring**

  Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to caprolactam dust exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of caprolactam dust on the eyes, skin, or respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

  Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for caprolactam dust.

- **Medical examinations recommended at the time of job transfer or termination**

  The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of placement should be repeated at the time of job transfer or termination to determine the worker's medical status at the end of his or her employment. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne caprolactam dust is determined by using an OSHA Versatile Sampler (OVS-7), 13-mm XAD-7 tube (270/140-mg sections, 20/60 mesh), with a glass fiber filter enclosed. Samples are collected at a maximum flow rate of 1 liter/min until a maximum air volume of 100 liters (TWA) or 15 liters (STEL) is collected. Analysis is conducted by high-performance liquid chromatography using an ultraviolet detector. This method is described in the OSHA Laboratory In-House Methods File [OSHA 1989].

PERSONAL HYGIENE

If caprolactam dust contacts the skin, workers should immediately wash the affected areas with soap and water.

Clothing contaminated with caprolactam dust should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed of the hazardous properties of caprolactam dust.

A worker who handles caprolactam dust should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, using toilet facilities, or applying cosmetics.

Workers should not eat, drink, use tobacco products, or apply cosmetics in areas where caprolactam dust is present.

STORAGE

Caprolactam should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. All electrical equipment in use in storage areas should be of explosionproof design. Carrying equipment and storage containers should be grounded and bonded to prevent a dust explosion, and bulk storage systems should have an explosion-relief design. Containers of caprolactam dust should be protected from physical damage and should be stored separately from strong oxidizers, heat, sparks, and open flame. Because containers that formerly contained caprolactam dust may still hold product residues, they should be handled appropriately.

SPILLS

In the event of a spill involving caprolactam dust, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a spill:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.

5. Cover spill with sand, vermiculite, or soda ash and place material into closed containers for later disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

  Caprolactam is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

  Employers are not required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center about an accidental release of caprolactam dust; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

  Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of caprolactam dust emitted or released from their facility annually.

- **Hazardous waste management requirements**

  EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although caprolactam dust is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [42 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

  Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

  Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of caprolactam dust exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. If the use of respirators is necessary, the only respirators permitted are those that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

  Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.1200]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, respirator fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective gloves and clothing should be worn to prevent skin contact with caprolactam dust. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to caprolactam dust permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to caprolactam dust.

If caprolactam dust is dissolved in water or an organic solvent, the permeation properties of both the solvent and the mixture must be considered when selecting personal protective equipment and clothing.

Safety glasses, goggles, or face shields should be worn during operations in which caprolactam dust might contact the eyes. Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with caprolactam dust. Contact lenses should not be worn if the potential exists for caprolactam dust exposure.

REFERENCES CITED

ACGIH [1991]. Documentation of the threshold limit values and biological exposure indices. 6th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [1993]. 1993-1994 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ATS [1987]. Standardization of spirometry—1987 update. American Thoracic Society. Am Rev Respir Dis 136:1285-1296.

CFR. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Hathaway GJ, Proctor NH, Hughes JP, Fischman ML [1991]. Chemical hazards of the workplace. Philadelphia, PA: J.B. Lippincott Company.

IARC [1986]. IARC monographs on the evaluation of carcinogenic risk of chemicals to humans. Vol. 39. Lyon, France: World Health Organization, International Agency for Research on Cancer.

NIOSH [1987a]. NIOSH guide to industrial respiratory protection. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-116.

NIOSH [1987b]. NIOSH respirator decision logic. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-108.

NIOSH [1992]. NIOSH recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

NIOSH [1993]. Registry of toxic effects of chemical substances database: caprolactam. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Standards Development and Technology Transfer, Technical Information Branch.

OSHA [1989]. OSHA laboratory in-house methods file. Salt Lake City, UT: U.S. Department of Labor, Occupational Safety and Health Administration, OSHA Analytical Laboratory.

OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR CAPROLACTAM VAPOR

INTRODUCTION

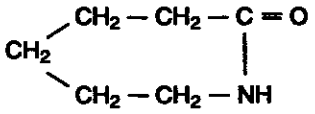
This guideline summarizes pertinent information about caprolactam vapor for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether new information is available.

SUBSTANCE IDENTIFICATION

- **Formula**

$C_6H_{11}NO$

- **Structure**



- **Synonyms**

Aminocaproic lactam; epsilon-caprolactam; 2-oxohexamethylenimine; 2-ketohexamethylenimine; 2-perhydroazepinone; Akulon; Alkamid; Amilan; ATM-2 (Nylon); Bonamid; Capran 80; Caprolon B; Capron; Chemlon; Danamid; Durethan BK; Grilon; Itamid; Kaprolit; Maranyl; Miramid; Orgamide; Nylon X 1051; Plaskin 8200; Spencer 401; Tarlon XB; Ultramid; Vidlon

- **Identifiers (For caprolactam)**

1. CAS No.: 105-60-2
2. RTECS No.: CM3675000
3. DOT UN: None
4. DOT label: None

- **Appearance and odor**

Caprolactam vapor is caprolactam in the vapor state. The vapor evolves only at high temperatures, because the vapor pressure of caprolactam is low. Caprolactam vapor is colorless and has an unpleasant odor.

CHEMICAL AND PHYSICAL PROPERTIES

(For caprolactam)

- **Physical data**

1. Molecular weight: 113.2
2. Boiling point (760 mm Hg): 266.9°C (512.42°F)
3. Specific gravity (water = 1): 1.02 at 75°C (167°F)
4. Vapor density (air = 1 at boiling point of caprolactam vapor): 3.9
5. Melting point: 70°C (158°F)
6. Vapor pressure at 20°C (682°F): 0.001 mm Hg

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Education and Information Division

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

7. Solubility: Soluble in water, benzene, chloroform, chlorinated hydrocarbons, cyclohexene, and petroleum fractions; freely soluble in methanol, ethanol, tetrahydrofurfuryl alcohol, ether, and dimethylformamide

8. Evaporation rate: Data not available

- **Reactivity**

1. Conditions contributing to instability: Moisture, heat, sparks, and open flame

2. Incompatibilities: Contact of caprolactam vapor with strong oxidizing agents should be avoided.

3. Hazardous decomposition products: Toxic gases (such as oxides of nitrogen) may be released in a fire involving caprolactam vapor.

4. Special precautions: None reported

- **Flammability**

The National Fire Protection Association has not assigned a flammability rating to caprolactam vapor; other sources rate caprolactam's fire hazard as slight.

1. Flash point: 125°C (257°F) (open cup)

2. Autoignition temperature: Data not available

3. Flammable limits in air (% by volume): Lower, 1.84; upper, 8.0

4. Extinguishant: Use carbon dioxide, dry chemical, alcohol foam, or water fog to fight fires involving caprolactam vapors. Water or foam may cause frothing. Do not use a solid stream of water because the stream will scatter and spread the fire. Water may be used to cool fire-exposed containers.

Fires involving caprolactam vapors should be fought upwind from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Firefighters should wear a full set of protective clothing and self-contained breathing apparatus when fighting fires involving caprolactam vapor.

EXPOSURE LIMITS

- **OSHA PEL**

The Occupational Safety and Health Administration (OSHA) has not promulgated a permissible exposure limit (PEL) for caprolactam vapor [29 CFR 1910.1000, Table Z-1].

- **NIOSH REL**

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 0.22 ppm (1 mg/m^3) as a TWA for up to a 10-hr workday and a 40-hr workweek and 0.66 ppm (3 mg/m^3) as a STEL. A STEL is the maximum 15-min concentration to which workers may be exposed during any 15-min period of the working day [NIOSH 1992].

- **ACGIH TLV**

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned caprolactam vapor a threshold limit value (TLV) of 5 ppm (23 mg/m^3) as a TWA for a normal 8-hr workday and a 40-hr workweek and a short-term exposure limit (STEL) of 10 ppm (46 mg/m^3) for periods not to exceed 15 min [ACGIH 1993].

- **Rationale for limits**

The NIOSH limits are based on the risk of convulsions, dermal and respiratory irritation, and dermal sensitization [NIOSH 1992]; the ACGIH limits are based on the risk of eye, skin, and upper respiratory tract irritation associated with exposure to caprolactam vapor [ACGIH 1991].

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Exposure to caprolactam vapor can occur through inhalation and eye or skin contact.

- **Summary of toxicology**

1. *Effects on Animals:* In animals, caprolactam vapor is an irritant of the eyes, upper respiratory tract, and skin and a central nervous system depressant. Applied to the skin of rabbits for 24 hr, 500 mg of caprolactam caused mild skin irritation; instilled into the eyes of rabbits, 20 mg of this substance caused a moderate degree of irritation [NIOSH 1993]. The dermal LD_{50} in rabbits is 1.4 g/kg [NIOSH 1993]. Acutely poisoned animals convulsed and showed other nervous system effects before death [NIOSH

1993]. The oral LD_{50} for caprolactam in rats is 1.2 g/kg; the LC_{50} in the same species is 300 mg/m^3 for 2 hr [NIOSH 1993]. Administered intraperitoneally, caprolactam at doses of 350 to 600 mg/kg caused tremor, convulsions, and a bloody eye discharge [Hathaway et al. 1991]. Guinea pigs tolerated seven daily 7-hr exposures to a concentration of caprolactam ranging from 118 to 261 mg/m^3 without evidence of adverse effects, other than occasional coughing [ACGIH 1991]. A 2-year carcinogenicity study of caprolactam in rats and mice showed negative results [IARC 1986].

2. *Effects on Humans:* Caprolactam is a convulsant and an irritant of the eyes, nose, and throat in humans [ACGIH 1991]. Exposure to this substance has also caused skin sensitization in some individuals [ACGIH 1991]. Repeated contact of the skin with the solid causes only transient irritation, in contrast to prolonged contact with the dust, which causes dermatitis [ACGIH 1991]. At vapor concentrations that occasionally peaked at 100 ppm (460 mg/m^3), polymer plant workers reported experiencing severe and dose-related eye, nose, and throat irritation; eye irritation was not experienced below a concentration of 25 ppm, but transient nose and throat irritation occurred in some workers even at vapor concentrations of 10 ppm (46 mg/m^3) [ACGIH 1991]. Volunteers exposed to caprolactam vapor for unspecified periods at concentrations ranging from 53 to 521 mg/m^3 reported eye and upper respiratory tract irritation [ACGIH 1991]. A group of male workers exposed to caprolactam and other chemicals showed an increase in sperm abnormalities, and women occupationally exposed to this substance are reported to have experienced an increased rate of complications during pregnancy; however, confounding exposures and other methodological problems make interpretation of these results difficult [IARC 1986].

- **Signs and symptoms of exposure**

1. *Acute exposure:* Acute exposure to caprolactam vapor may cause redness, inflammation, and burning of the eyes; runny nose; scratchy throat; productive cough; transient skin redness; nose bleeds; a bitter taste in the mouth; and a feeling of nervousness.

2. *Chronic exposure:* No signs or symptoms of chronic exposure to caprolactam vapor have been reported.

- **Emergency procedures**

> **WARNING!**
>
> **Seek immediate medical attention for severely affected victims or for victims with signs and symptoms of toxicity or irritation!**

Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. Initiate the following emergency procedures:

1. *Eye exposure:* Irritation may result. ***Immediately and thoroughly*** flush the eyes with large amounts of water, occasionally lifting the upper and lower eyelids.

2. *Skin exposure:* Irritation may result. ***Thoroughly*** wash contaminated skin with soap and water.

3. *Inhalation exposure:* Move the victim to fresh air ***immediately.***

   If the victim is not breathing, clean any chemical contamination from the victim's lips and perform cardiopulmonary resuscitation (CPR); if breathing is difficult, give oxygen.

4. *Rescue:* Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the material safety data sheet required by OSHA's hazard communication standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures, the location and proper use of emergency equipment, and methods of protecting themselves during an emergency.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve caprolactam vapor and may result in worker exposures to this substance:

—Use as a chemical intermediate in the production of nylon-6 fibers and plastics

—Use as a solvent for some high molecular weight polymers

—Use in making coatings, plasticizers, paint vehicles, and synthetic leather

The following methods are effective in controlling worker exposures to caprolactam vapor, depending on the feasibility of implementation:

—Process enclosure

—Local exhaust ventilation

—General dilution ventilation

—Personal protective equipment

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation—a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation—a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL MONITORING

Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and personal protective equipment). A medical monitoring program is intended to supplement, not replace, such measures. To place workers effectively and to detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

- **Preplacement medical evaluation**

Before a worker is placed in a job with a potential for exposure to caprolactam vapor, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the eyes, skin, and respiratory system. Medical monitoring for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society [ATS 1987].

A preplacement medical evaluation is recommended to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to caprolactam vapor at or below the prescribed exposure limit. The health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with diseases of the eyes, skin, or respiratory system.

- **Periodic medical examinations and biological monitoring**

Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to caprolactam vapor exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of caprolactam vapor on the eyes, skin, or respiratory system. Current health status should be compared with the baseline health status of the individ-

ual worker or with expected values for a suitable reference population.

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. No biological monitoring test acceptable for routine use has yet been developed for caprolactam vapor.

- **Medical examinations recommended at the time of job transfer or termination**

The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of placement should be repeated at the time of job transfer or termination. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

WORKPLACE MONITORING AND MEASUREMENT

A worker's exposure to airborne caprolactam vapor is determined by using an OSHA Versatile Sampler (OVS7), 13-mm XAD-7 tube (270/140-mg sections, 20/60 mesh), with glass fiber filter enclosed. Samples are collected at a maximum flow rate of 1 liter/min until a maximum air volume of 100 liters (TWA) or 15 liters (STEL) is collected. Analysis is conducted by high-performance liquid chromatography using an ultraviolet detector. This method is described in the OSHA Laboratory In-House Methods File [OSHA 1989].

PERSONAL HYGIENE

If caprolactam vapor contacts the skin, workers should immediately wash the affected areas with soap and water.

Clothing contaminated with caprolactam vapor should be removed immediately, and provisions should be made for safely removing this chemical from these articles. Persons laudering contaminated clothing should be informed of the hazardous properties of caprolactam vapor.

A worker who is exposed to caprolactam vapor should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, using toilet facilities, or applying cosmetics.

Workers should not eat, drink, use tobacco products, or apply cosmetics in areas where caprolactam vapor is present.

STORAGE

Caprolactam should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. All electrical equipment in use in storage areas should be of explosionproof design. Containers of caprolactam vapor should be protected from physical damage and should be stored separately from strong oxidizers, heat, sparks, and open flame. To prevent static sparks, containers should be grounded and bonded for transfers. Because containers that formerly contained caprolactam vapor may still hold product residues, they should be handled appropriately.

LEAKS

In the event of a leak involving caprolactam vapor, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup is complete. The following steps should be undertaken following a leak:

1. Do not touch the leaked material.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Ventilate potentially explosive atmospheres.
5. Cover the leaked material with sand, vermiculite, or soda ash and place material into closed containers for later disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

- **Emergency planning requirements**

Caprolactam vapor is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) [42 USC 11022].

- **Reportable quantity requirements for hazardous releases**

Employers are not required by the emergency release

notification provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [40 CFR 355.40] to notify the National Response Center of an accidental release of caprolactam vapor; there is no reportable quantity for this substance.

- **Community right-to-know requirements**

Employers are not required by Section 313 of SARA to submit a Toxic Chemical Release Inventory Form (Form R) to EPA reporting the amount of caprolactam vapor emitted or released from their facility annually.

- **Hazardous waste management requirements**

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Although caprolactam vapor is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [42 USC 6901 et seq.], EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (800) 424-9346 or at (202) 382-3000 in Washington, D.C. In addition, relevant State and local authorities should be contacted for information about their requirements for waste removal and disposal.

RESPIRATORY PROTECTION

- **Conditions for respirator use**

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of caprolactam vapor exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should use only respirators approved by NIOSH and the Mine Safety and Health Administration (MSHA).

- **Respiratory protection program**

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's respiratory protection standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, respirator fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information about the selection and use of respirators and about the medical screening of respirator users, consult the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Protective gloves and clothing should be worn to prevent skin contact with caprolactam vapor. Chemical protective clothing should be selected on the basis of available performance data, manufacturers' recommendations, and evaluation of the clothing under actual conditions of use. No reports have been published on the resistance of various protective clothing materials to caprolactam vapor permeation. If permeability data are not readily available, protective clothing manufacturers should be requested to provide information on the best chemical protective clothing for workers to wear when they are exposed to caprolactam vapor.

Safety glasses, goggles, or face shields should be worn during operations in which caprolactam vapor might contact the eyes. Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with caprolactam vapor. Contact lenses should not be worn if the potential exists for caprolactam vapor exposure.

REFERENCES CITED

ACGIH [1991]. Documentation of the threshold limit values and biological exposure indices. 6th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [1993]. 1993-1994 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ATS [1987]. Standardization of spirometry—1987 update. American Thoracic Society. Am Rev Respir Dis 136:1285-1296.

CFR. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Hathaway GJ, Proctor NH, Hughes JP, Fischman ML [1991]. Chemical hazards of the workplace. Philadelphia, PA: J.B. Lippincott Company.

IARC [1986]. IARC monographs on the evaluation of carcinogenic risk of chemicals to humans. Vol. 39. Lyon, France: World Health Organization, International Agency for Research on Cancer.

NIOSH [1987a]. NIOSH guide to industrial respiratory protection. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-116.

NIOSH [1987b]. NIOSH respirator decision logic. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-108.

NIOSH [1992]. NIOSH recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

NIOSH [1993]. Registry of toxic effects of chemical substances database: caprolactam. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Standards Development and Technology Transfer, Technical Information Branch.

OSHA [1989]. OSHA laboratory in-house methods file. Salt Lake City, UT: U.S. Department of Labor, Occupational Safety and Health Administration, OSHA Analytical Laboratory.