

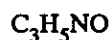
OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ACRYLAMIDE

INTRODUCTION

This guideline summarizes pertinent information about acrylamide 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 Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine periodically whether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



• Structure



• Synonyms

Acrylic amide; propenamide; 2-propenamide; propenoic acid amide; acrylamide monomer

• Identifiers

1. CAS No.: 79-06-1
2. RTECS No.: AS3325000
3. DOT UN: 2074 55
4. DOT label: St. Andrew's Cross

• Appearance and odor

Acrylamide is a colorless to white, odorless, crystalline solid.

CHEMICAL AND PHYSICAL PROPERTIES

• Physical data

1. Molecular weight: 71.1
2. Boiling point (at 760 mm Hg): 175° to 300°C (347° to 572°F); decomposes on boiling
3. Specific gravity (water = 1): 1.1 at 30°C (86°F)
4. Vapor density (air = 1 at boiling point of acrylamide): 2.4
5. Melting point: 84.5°C (179.3°F)
6. Vapor pressure at 20°C (68°F): 0.007 mm Hg
7. Solubility: Miscible with water; soluble in acetone, ethanol, ethyl ether, and methanol
8. Evaporation rate: Data not available

• Reactivity

1. Conditions contributing to instability: Acrylamide decomposes above 175°C (347°F). Violent polymerization may occur when heated or when exposed to ultraviolet light.
2. Incompatibilities: Fires and explosions may result from contact of acrylamide with strong oxidizers.
3. Thermal decomposition products: Toxic gases (such as ammonia, hydrogen, and carbon monoxide) may be released when acrylamide decomposes; toxic oxides of nitrogen may form in fire.
4. Special precautions: None

• Flammability

Acrylamide is combustible, but because of its high flash point, it is considered only a slight fire hazard when exposed to heat, sparks, or open flame. It is a combustible, flammable liquid when dissolved in solvent. The National Fire Protection Association has not assigned a flammability rating to

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Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

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acrylamide; other sources rate acrylamide as a moderate fire hazard.

1. Flash point: 138°C (280°F) (closed cup)
2. Autoignition temperature: 424°C (795°F)
3. Flammable limits in air (% by volume): Data not available
4. Extinguishant: Use dry chemical, carbon dioxide, Halon®, water spray, or standard foam for small fires; water spray, fog, or standard foam for large fires.

Fires involving acrylamide should be fought upwind and from the maximum distance possible. Isolate the hazard area and deny access to unnecessary personnel. Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Containers of acrylamide may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool the containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if they hear a rising sound from a venting safety device or if a container becomes discolored as a result of fire. Dikes should be used to contain fire-control water for later disposal. Firefighters should wear a full set of protective clothing (including a self-contained breathing apparatus) when fighting fires involving acrylamide. Chemical protective clothing specifically recommended for acrylamide may not provide thermal protection unless so stated by the clothing manufacturer. Firefighters' protective clothing may not provide protection against permeation by acrylamide.

EXPOSURE LIMITS

• OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for acrylamide is 0.03 mg/m³ as an 8-hr time-weighted average (TWA) concentration. The OSHA PEL also bears a "Skin" designation, which indicates that the cutaneous route of exposure (including mucous membranes and eyes) contributes to overall exposure [29 CFR 1910.1000, Table Z-1-A].

• NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) of 0.03 mg/m³ as an 8-hr TWA with a "Skin" notation. However, acrylamide has been designated as a potential occupational carcinogen and exposure should be limited to the lowest feasible concentration [NIOSH 1992].

• ACGIH TLV®

The American Conference of Governmental Industrial Hygienists (ACGIH) has designated acrylamide an A2 substance (suspected human carcinogen) and assigned

acrylamide a threshold limit value (TLV) of 0.03 mg/m³ as a TWA for a normal 8-hr workday and a 40-hr workweek with a "Skin" notation [ACGIH 1991b].

• Rationale for limits

The limits are based on the risk of systemic poisoning associated with exposure to acrylamide.

HEALTH HAZARD INFORMATION

• Routes of exposure

Exposure to acrylamide can occur through inhalation of vapor, dust, or aerosol and absorption through the skin or mucous membranes.

• Summary of toxicology

1. *Effects on Animals:* Acrylamide is an irritant, a potent neurotoxin that affects both the central and peripheral nervous systems, a reproductive toxin, and a carcinogen. A 10% aqueous solution of acrylamide applied to abraded rabbit skin caused tissue swelling and redness. Although the 10% aqueous solution immediately caused slight pain and conjunctival irritation, a 40% solution produced severe pain with minimal corneal damage. This damage was repaired within 24 hr following a nonrinsed ocular application [Grant 1986]. Acrylamide is also a moderate skin irritant. The acute dermal LD₅₀ in rabbits is 2,250 mg/kg [ACGIH 1991a]. The acute oral LD₅₀ for rats, guinea pigs, and rabbits fed aqueous solutions of 2.5% to 12.6% acrylamide ranged from 150 to 180 mg/kg body weight. However, in rats fed a 50% aqueous solution of acrylamide, the LD₅₀ was 565 mg/kg and 490 mg/kg for males and females, respectively. The acute lethality of acrylamide is a result of its neurotoxic effects, especially on the central nervous system. The toxic effects of acrylamide on the central nervous system are reversible if the dose and duration of exposure are minimal. Recovery is greatly prolonged if the exposure duration is increased [ACGIH 1991a].

Severe or lethal exposure concentrations can also induce testicular degeneration of the seminephrous tubules, degeneration of the convoluted tubular epithelium of the kidney, fatty degeneration and necrosis of the liver, and congestion of the lungs [NLM 1991]. The primary effects of repeated exposures are neurotoxic and involve the central and peripheral nervous systems. The central nervous system effects predominate during acute and subchronic exposures and can also involve somnolence and hallucinations. The sensory and motor neuronal effects on the peripheral nervous system (such as distal numbness, paresthesias, sensory loss, weakness, ataxia, and paralysis) predominate during chronic exposures [NLM 1991]. Rats, cats, and monkeys have developed neuropathies only when exposed to repeated daily doses of 1 mg/kg or more [ACGIH 1991a].

Male rats and mice that received neurotoxic concentrations of acrylamide orally for 2 to 3 months developed testicular degeneration. The rats consumed 20 mg/kg of body weight per day from drinking water, which contained 400 ppm. The mice received doses of 35.5 mg/kg twice per week [NLM 1991]. Chromosomal alterations in the sperm (but not bone marrow) cells of male DDY mice exposed to acrylamide have also been reported [Sakamoto and Hashimoto 1986]. Although pregnant rats that consumed a diet containing 400 ppm throughout their gestation period developed maternal toxicity (neurotoxicity), only slightly depressed birth weights were noted in their pups [ACGIH 1991a]. Similar consumption of a 200-ppm diet induced an abnormal gait in the pregnant dams but did not affect the growth and development of offspring during their first 6 weeks of postnatal development [ACGIH 1991a]. No developmental defects were induced in fetuses of pregnant dams intubated with 20 mg/kg per day (200 mg/kg total dose) during days 6 to 17 of gestation [NLM 1991].

Studies in mice and rats confirm that acrylamide can act either as an initiator or as a complete carcinogen [NIOSH 1991]. This chemical induces skin-tumor-initiating activity in Sencar mice and lung tumors in A/J mice. Acrylamide administered in drinking water to F344 rats for 2 years caused a statistically increased number of tumors (including cancerous tumors) at multiple sites. The International Agency for Research on Cancer (IARC) found "sufficient evidence of carcinogenicity" for chronically exposed animals [IARC 1986].

2. Effects on Humans: Most cases of acrylamide toxicity in humans have resulted from occupational exposures, especially transcutaneous ones. In these cases, episodic contact dermatitis of the hands is usually observed before signs of severe neuropathy become apparent. Workers exposed through the skin to acrylamide dust for 1 to 24 months developed characteristic neurological signs that consisted of postural difficulty, ataxia, lethargy, loss of vibratory sensation, loss of deep tendon reflexes, loss of position sense, and weakness, numbness, and tingling of the extremities. In addition, the extremities were cold and bluish-red in color. The palms of the hands and soles of the feet sweated excessively, and skin peeled from the hands and fingers [Sax 1984; Schaumburg et al. 1983].

Acrylamide toxicity resulting from ingestion of subacute doses (such as in contaminated drinking water) is manifested by central nervous system neuropathy. Drowsiness, disturbed balance, confusion, memory loss, and hallucinations have all been reported following ingestion of acrylamide. Nystagmus and slurred speech have also been noted. Disturbances of vision have not been observed in cases of systemic acrylamide toxicity. In systemic acrylamide poisoning, peripheral neuropathy is late to appear relative to central

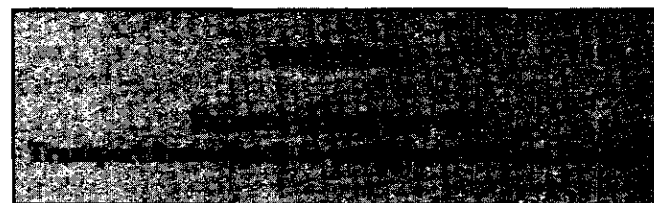
nervous system effects. The signs and symptoms of acrylamide toxicity remit slowly, and often only partially, following cessation of exposure. Although IARC could find no adequate data that demonstrate an increased cancer incidence in acrylamide-exposed workers, they classify the chemical as 2B, "possibly carcinogenic to humans." This classification is based on the induction of cancers in exposed experimental animals [IARC 1987].

• Signs and symptoms of exposure

1. **Acute exposure:** Exposure to acrylamide can cause irritation, muscular stiffness and weakness, ataxia, loss of balance, loss of proprioception, and ability to stand.

2. **Chronic exposure:** Exposure to acrylamide can cause irritation, peeling of the skin and excessive sweating of the hands and feet, somnolence, confusion, hallucinations, memory loss, numbness, sensory loss, loss of tendon reflexes, weakness, nystagmus, slurred speech, incoordination, tremor, muscular atrophy, ataxia, and paralysis.

• Emergency procedures



Keep unconscious victims warm and on their sides to avoid choking if vomiting occurs. **Immediately** initiate the following emergency procedures, continuing them as appropriate en route to the emergency medical facility:

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:** Acrylamide can cause skin irritation. **Immediately** remove contaminated clothing and **thoroughly** wash contaminated skin with soap and water.

3. **Inhalation exposure:** If respirable acrylamide is inhaled, move the victim to fresh air **immediately**. Have the victim blow his or her nose, or use a soft tissue to swab particulates 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 acrylamide 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 giving syrup of ipecac as directed on the package. If ipecac is unavailable, have the victim touch the back of the throat with a finger until productive vomiting ceases.

—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 and the location and proper use of emergency equipment.

EXPOSURE SOURCES AND CONTROL METHODS

The following uses of acrylamide may result in worker exposures to this substance:

—Use in the manufacture of copolymers and polyacrylamides for use as flocculating and thickening agents in pulp and paper industries, oil production, mining textiles, surface coating, adhesives, dyes, photography, and water and waste treatment

—Use as a grouting material in oil wells, basements, tunnels, mine shafts, caissons, and dams

—Use in miscellaneous processes of monomer acrylamide as a curing agent and in organic synthesis

—Use in soap and cosmetic preparations as thickeners and in preshave lotions, hair grooming preparations, and denture fixtures

—Use in stabilizing soil and in permitting the free flow of foundry sand into molds

—Use in clarifying solutions in chemical and food manufacturing; use in gel form in electrophoresis procedures in laboratories

The following methods are effective in controlling worker exposures to acrylamide, 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, placement of workers in jobs that do not jeopardize their safety or health, 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 acrylamide, 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 central nervous system 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 assess an individual's suitability for employment at a specific job and to detect and assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to acrylamide at or below the prescribed exposure limit. The licensed 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 or findings consistent with seizure or other central nervous system disorders or chronic respiratory disease.

- **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 acrylamide exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of acrylamide on the central nervous system and 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 tissue 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 acrylamide.

- **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 job 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 acrylamide is determined by using a personal sampling train consisting of a glass fiber filter in a Swinnex cassette (13 mm) followed by a silica gel tube. Plastic cassettes (37 mm) yielded poor recoveries of acrylamide and are therefore unsuitable. Samples are collected at a maximum flow rate of 1.0 liter/min until a maximum air volume of 120 liters is collected. The silica gel tube should then be treated with methanol to extract the acrylamide. An important step in this method is the transfer of the glass-fiber filters to glass vials containing 1 ml of methanol immediately after sampling to avoid losses of acrylamide from the filter by evaporation. The sample is then analyzed by gas chromatography using a nitrogen/

phosphorous detector. The limit of detection for this procedure is 1.3 parts per billion (ppb) (0.004 mg/m³). This method (Method 21) is included in the OSHA Computerized Information System [OSHA 1986]. The NIOSH procedure (Method S158) is described in the *NIOSH Manual of Analytical Methods* [NIOSH 1984].

PERSONAL HYGIENE

Because acrylamide can be absorbed through the skin in lethal amounts, workers should immediately remove any contaminated clothing and then should wash thoroughly with soap and water any areas of the skin that have come in contact with this substance.

Clothing and shoes contaminated with acrylamide should be removed immediately and provisions should be made for safely removing this chemical from these articles. Persons laundering contaminated clothing should be informed about the hazardous properties of acrylamide, particularly its *potential for being absorbed through the skin in lethal amounts*.

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

Workers should not eat, drink, or use tobacco products in areas where acrylamide is handled, processed, or stored.

STORAGE

Acrylamide should be stored in a dark, dry, well-ventilated refrigerated area in tightly sealed containers that are labeled in accordance with OSHA's hazard communication standard [29 CFR 1910.1200]. Storage in an inert atmosphere is recommended. All electrical service in storage areas should be of explosionproof design. Containers of acrylamide should be protected from physical damage and should be stored separately from oxidizing agents, polymerization catalysts, heat, sparks, and open flame. Because empty containers may contain acrylamide residues, they should be handled appropriately.

SPILLS AND LEAKS

In the event of a spill or leak involving acrylamide, 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 or leak:

1. Do not touch the spilled material.
2. Notify safety personnel.
3. Remove all sources of heat and ignition.
4. Provide maximum explosionproof ventilation.

5. Use nonsparking tools during cleanup.
6. Carefully collect solid material using sand, vermiculite, or soda ash and place in a covered container for disposal.
7. To the extent feasible, avoid generating dust during cleanup.

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**

Acrylamide 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 acrylamide; 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 acrylamide 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 acrylamide is not specifically listed as a hazardous waste under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA requires employers to treat any 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 acrylamide 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 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 1910.134]. 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, 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 clothing should be worn to prevent any possibility of skin contact with acrylamide. Gloves, apron, boots, and a chemical protective suit should be worn when workers are handling this substance. 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. Polyethylene/ethylene vinyl alcohol has been tested against permeation by acrylamide and has demonstrated good-to-excellent resistance for periods of 4 to 8 hr.

If acrylamide 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 acrylamide might contact the eyes (e.g., through dust particles or splashes of solution). Eyewash fountains and emergency showers should be available within the immediate work area whenever the potential exists for eye or skin contact with acrylamide. Contact lenses should not be worn if the potential exists for acrylamide exposure.

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