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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR INORGANIC ARSENIC AND ITS COMPOUNDS (as As) POTENTIAL HUMAN CARCINOGEN

INTRODUCTION

"Inorganic arsenic" is defined as elemental arsenic and all of its inorganic compounds except arsine (see guideline for arsine). This guideline summarizes pertinent information about inorganic arsenic for workers, employers, and 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 Recommendations may be superseded by new developments in these fields; therefore, readers are advised to regard these recommendations as general guidelines.

SUBSTANCE IDENTIFICATION

Data in the following section are presented for elemental arsenic.

- **Formula:** As
- **Synonyms:** Arsenic black, arsenic-75, arsenic solid, arsenic metallic, arsenicals, grey arsenic
- **Identifiers:** CAS 7440-38-2; RTECS CG0525000; DOT 1558, label required: "Poison"
- **Appearance and odor:** Gray metal with an odor like garlic when heated

CHEMICAL AND PHYSICAL PROPERTIES

Data in the following section are presented for elemental arsenic.

- **Physical data**
 1. Molecular weight: 74.92
 2. Boiling point (at 760 mmHg): 613°C (1,135°F), sublimes
 3. Specific gravity (water = 1): 5.73
 4. Vapor density (air = 1 at sublimation point of arsenic): 2.6
 5. Melting point: Sublimes at 613°C (1,135°F)
 6. Insoluble in water
- **Reactivity**
 1. Incompatibilities: Oxidizing agents and heat
 2. Hazardous decomposition products: Toxic gases and vapors

or fumes (e.g., arsenic oxide fume) may be released in a fire involving arsenic.

3. Caution: Hydrogen gas can react with inorganic arsenic to form arsine.

- **Flammability**

1. Extinguishant: All firefighting agents, except soda-acid
2. Caution: Arsenic is combustible in powder form or by chemical reaction with powerful oxidizers such as bromates, chlorates, iodates, and peroxides.

- **Warning properties**

Evaluation of warning properties for respirator selection: Warning properties are not considered in recommending respirators for use with carcinogens.

EXPOSURE LIMITS

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for inorganic arsenic (except arsine) is 0.01 milligrams of arsenic per cubic meter of air (mg/m^3) as a time-weighted average (TWA) over an 8-hour workshift. The National Institute for Occupational Safety and Health (NIOSH) recommends that arsenic and all its inorganic compounds be controlled and handled as potential human carcinogens in the workplace and that exposure be minimized to the lowest feasible limit. The NIOSH recommended exposure limit (REL) for arsenic and all its inorganic compounds is $0.002 \text{ mg}/\text{m}^3$ as a ceiling concentration determined in any 15-minute sampling period. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV[®]) for soluble arsenic compounds is $0.2 \text{ mg}/\text{m}^3$ as a TWA for a normal 8-hour workday and a 40-hour workweek. The ACGIH has designated arsenic trioxide production as A2 (suspected human carcinogen) without having sufficient evidence to assign a TLV[®] (Table 1).

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Inorganic arsenic compounds may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Standards Development and Technology Transfer

Table 1.—Occupational exposure limits for inorganic arsenic and its compounds (as As)

	Arsenic and its inorganic compounds	Arsenic compounds, soluble	Arsenic trioxide production
	mg/m ³	mg/m ³	mg/m ³
OSHA PEL TWA	0.01	—	—
NIOSH REL (Ca)*			
Ceiling (15 min)	0.002	—	—
ACGIH TLV® (TWA)	—	0.2	(A2)†

* (Ca): NIOSH recommends treating as a potential human carcinogen.

† (A2): Suspected human carcinogen.

• Summary of toxicology

1. *Effects on animals:* Chronic ingestion or inhalation of inorganic arsenic by rats caused marked enlargement of the common bile duct and fatty degeneration of the liver. Injection of arsenic in pregnant rats, mice, and hamsters caused malformations of the offspring.

2. *Effects on humans:* Inhalation, ingestion, or dermal exposure of workers to inorganic arsenic has caused peripheral nerve inflammation (neuritis) and degeneration (neuropathy), reduced peripheral circulation, anemia, increased mortality due to cardiovascular failure, and cancers of the skin, lungs, and lymphatic system.

• Signs and symptoms of exposure

1. *Short-term (acute):* Exposure to inorganic arsenic can cause nausea, vomiting, diarrhea, weakness, loss of appetite, cough, chest pain, giddiness, headache, and breathing difficulty (dyspnea).

2. *Long-term (chronic):* Exposure to inorganic arsenic can cause weakness, nausea, vomiting, diarrhea, skin and eye irritation, hyperpigmentation, thickening of the palms and soles (hyperkeratosis), contact dermatitis, skin sensitization, warts, ulceration and perforation of the nasal septum, and numbness and weakness in the legs and feet.

RECOMMENDED MEDICAL PRACTICES

• Medical surveillance program

Workers with potential exposures to chemical hazards should be monitored in a systematic program of medical surveillance intended to prevent or control 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 and health, earliest possible detection of adverse health effects, and referral of workers for diagnostic confirmation and treatment. The occurrence of disease (a "sentinel health event," SHE) or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and per-

sonal protective equipment). A medical surveillance program is intended to supplement, not replace, such measures.

A medical surveillance program should include systematic collection and epidemiologic analysis of relevant environmental and biologic monitoring, medical screening, morbidity, and mortality data. This analysis may provide information about the relatedness of adverse health effects and occupational exposure that cannot be discerned from results in individual workers. Sensitivity, specificity, and predictive values of biologic monitoring and medical screening tests should be evaluated on an industry-wide basis prior to application in any given worker group. Intrinsic to a surveillance program is the dissemination of summary data to those who need to know, including employers, occupational health professionals, potentially exposed workers, and regulatory and public health agencies.

• Preplacement medical evaluation

Prior to placing a worker in a job with a potential for exposure to inorganic arsenic, the physician 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 skin, peripheral nervous system, liver, lymphatic and hematopoietic (blood cell forming) systems, and respiratory tract. Medical surveillance for respiratory disease should be conducted by using the principles and methods recommended by NIOSH and the American Thoracic Society (ATS).

A preplacement medical evaluation is recommended in order to detect and assess preexisting or concurrent conditions which may be aggravated or result in increased risk when a worker is exposed to inorganic arsenic and its compounds at or below the NIOSH REL. The examining physician should consider the probable frequency, intensity, and duration of exposure, as well as the nature and degree of the condition, in placing such a worker. Such conditions, which should not be regarded as absolute contraindications to job placement, include concurrent dermatitis or peripheral neuropathy, a history and other findings consistent with chronic disease of the skin or nervous system, and significant breathing impairment due to preexisting chronic lung disease.

• Periodic medical screening and/or biologic monitoring

Occupational health interviews and physical examinations should be performed at regular intervals. Additional examinations may be necessary should a worker develop symptoms that may be attributed to exposure to inorganic arsenic. The interviews, examinations, and appropriate medical screening and/or biologic monitoring tests should be directed at identifying an excessive decrease or adverse trend in the physiologic function of the skin, blood, lymphatic system, peripheral nervous system, liver, and respiratory tract as compared to the baseline status of the individual worker or to expected values for a suitable reference population. The following tests should be used and interpreted according to standardized procedures and evaluation criteria recommended by NIOSH

and ATS: standardized questionnaires and tests of lung function.

- **Medical practices 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 which 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 to those expected for a suitable reference population. Because occupational exposure to inorganic arsenic and its compounds may cause diseases of prolonged induction-latency, the need for medical surveillance may extend well beyond termination of employment.

- **Sentinel health events**

Delayed-onset SHE's include: Inflammatory and toxic neuropathy, agranulocytosis or neutropenia (absence or a severe decrease in the number of certain white blood cells), and cancers of the liver and respiratory tract.

MONITORING AND MEASUREMENT PROCEDURES

- **Ceiling concentration evaluation**

Measurements to determine worker exposure should be taken during periods of maximum expected airborne concentrations of inorganic arsenic. Each measurement to determine the NIOSH REL (ceiling exposure) in the worker's breathing zone (air that most nearly represents that inhaled by the worker) should consist of a 15-minute sample or a series of consecutive samples that total 15 minutes. A minimum of three measurements should be taken during one workshift, and the highest of all measurements taken is an estimate of the worker's exposure. If the periods of maximum exposure are not clearly defined, a statistical procedure which can be used as a peak exposure detection strategy is given in the *Occupational Exposure Sampling Strategy Manual*.

- **Method**

Sampling and analysis may be performed by collecting particulate inorganic arsenic with cellulose membrane filters followed by digestion with acid and analysis by atomic absorption with flame arsine generation. A detailed sampling and analytical method may be found in the *NIOSH Manual of Analytical Methods* (method number 7900).

PERSONAL PROTECTIVE EQUIPMENT

Chemical protective clothing (CPC) should be selected after utilizing available performance data, consulting with the manufacturer, and then evaluating the clothing under actual use conditions.

Workers should be provided with and required to use CPC, gloves, and other appropriate protective clothing necessary to prevent skin contact with inorganic arsenic.

SANITATION

Clothing which is contaminated with inorganic arsenic should be removed immediately and placed in sealed containers for

storage until it can be discarded or until provision is made for the removal of inorganic arsenic from the clothing. If the clothing is to be laundered or cleaned, the person performing the operation should be informed of inorganic arsenic's hazardous properties. Reusable clothing and equipment should be checked for residual contamination before reuse or storage.

A change room with showers, washing facilities, and lockers that permit separation of street and work clothes should be provided.

Workers should be required to shower following a workshift and prior to putting on street clothes. Clean work clothes should be provided daily.

Skin that becomes contaminated with inorganic arsenic should be promptly washed with soap and water.

The storage, preparation, dispensing, or consumption of food or beverages, the storage or application of cosmetics, the storage or smoking of tobacco or other smoking materials, and the storage or use of products for chewing should be prohibited in work areas.

Workers who handle inorganic arsenic should wash their faces, hands, and forearms thoroughly with soap and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

Common operations in which exposure to inorganic arsenic may occur and control methods which may be effective in each case are listed in Table 2.

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, remove the victim from further exposure, send for medical assistance, and initiate emergency procedures.

- **Eye exposure**

Where there is any possibility of a worker's eyes being exposed to inorganic arsenic, an eyewash fountain should be provided within the immediate work area for emergency use.

If inorganic arsenic gets into the eyes, flush them immediately with large amounts of water for 15 minutes, lifting the lower and upper lids occasionally. Get medical attention as soon as possible. Contact lenses should not be worn when working with this chemical.

- **Skin exposure**

Where there is any possibility of a worker's body being exposed to inorganic arsenic, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.

If inorganic arsenic gets on the skin, wash it immediately with soap and water. If inorganic arsenic penetrates the clothing, remove the clothing promptly and wash the skin with soap and water. Get medical attention promptly.

Table 2.—Operations and methods of control for inorganic arsenic

Operations	Controls
During the manufacture of insecticides, weed killers and fungicides; during use as a wood preservative	Process enclosure, local exhaust ventilation, personal protective equipment
During use in the manufacture and handling of calcium arsenate; during use in the manufacture of electrical semiconductors, diodes, and solar batteries	Process enclosure, local exhaust ventilation, personal protective equipment
During use as a bronzing or decolorizing addition in glass manufacturing; during use in the production of opal glass and enamels	Process enclosure, local exhaust ventilation, personal protective equipment
During use as an addition to alloys to increase hardening and heat resistance	Process enclosure, local exhaust ventilation, personal protective equipment
During smelting of ores	Local exhaust ventilation, personal protective equipment

• **Rescue**

If a worker has been incapacitated, move the affected worker from the hazardous exposure. Put into effect the established emergency rescue procedures. Do not become a casualty. Understand the facility's emergency rescue procedures and know the locations of rescue equipment before the need arises.

SPILLS AND LEAKS

Workers not wearing protective equipment and clothing should be restricted from areas of spills or leaks until cleanup has been completed.

If inorganic arsenic or its compounds are spilled, the following steps should be taken:

1. Remove all ignition sources.
2. Ventilate area of spill.
3. For small quantities of liquids containing inorganic arsenic, absorb on paper towels and place in an appropriate container.
4. Large quantities of liquids containing inorganic arsenic may be absorbed in vermiculite, dry sand, earth, or a similar material and placed in an appropriate container.
5. Inorganic arsenic dust may be collected by vacuuming with an appropriate high-efficiency filtration system. If a vacuum system is used, there should be no sources of ignition in the vicinity of the spill, and flashback prevention devices should be provided.

WASTE REMOVAL AND DISPOSAL

U.S. Environmental Protection Agency, Department of Transportation, and/or state and local regulations shall be followed to assure that removal, transport, and disposal are in accordance with existing regulations.

RESPIRATORY PROTECTION

It must be stressed that the use of respirators is the least preferred method of controlling worker exposure and should not normally be used as the only means of preventing or minimizing exposure during routine operations. However, there are some exceptions for which respirators may be used to control exposure: when engineering and work practice controls are not technically feasible, when engineering controls are in the process of being installed, or during emergencies and certain maintenance operations including those requiring confined-space entry (Table 3).

In addition to respirator selection, a complete respiratory protection program should be instituted which as a minimum complies with the requirements found in the OSHA Safety and Health Standards 29 CFR 1910.134. A respiratory protection program should include as a minimum an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, fit testing, periodic environmental monitoring, maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program, including selection of the correct respirators, requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly.

Only respirators that have been approved by the Mine Safety and Health Administration (MSHA, formerly Mining Enforcement and Safety Administration) and by NIOSH should be used. **Remember! Air-purifying respirators will not protect from oxygen-deficient atmospheres.**

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Table 3.—Respiratory protection for inorganic arsenic

Condition	Minimum respiratory protection*
Any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Planned or emergency entry into environments containing unknown or any detectable concentration	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode Any supplied-air respirator with a full facepiece and operated in a pressure-demand or other positive pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive pressure mode
Firefighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	Any air-purifying full facepiece respirator (gas mask) with a chin-style or front- or back-mounted acid gas canister having a high-efficiency particulate filter Any appropriate escape-type self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment should be used.