Occupational Health Guideline for Uranium and Insoluble Compounds (as Uranium)

INTRODUCTION

This guideline is intended as a source of information for employees, employers, physicians, industrial hygienists, and other occupational health professionals who may have a need for such information. It does not attempt to present all data; rather, it presents pertinent information and data in summary form.

APPLICABILITY

The general guidelines contained in this document apply to all uranium and insoluble compounds. Physical and chemical properties of several specific compounds are provided for illustrative purposes.

SUBSTANCE IDENTIFICATION

Metallic uranium

- Formula: U
- Synonyms: None
- Appearance: Heavy, silvery white metal which is pyrophoric when finely divided.
- Note: U238 is radioactive with a half life of 4,900,000,000 years.

Uranium octaoxide

- Formula: U_3O_8
- Synonyms: Pitchblende
- Appearance and odor: Black, odorless solid.

Uranium tetrafluoride

- Formula: UF_4
- Synonyms: None
- Appearance and odor: Green, odorless solid.

Uranium hydride

- Formula: UH_3
- Synonyms: None
- Appearance: Brownish black or brownish gray powder.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for uranium or insoluble compounds is 0.25 milligram of uranium or insoluble compounds (as uranium) per cubic meter of air (mg/m^3) averaged over an eight-hour work shift. The American Conference of Governmental Industrial Hygienists has recommended for uranium or insoluble compounds (as uranium) a Threshold Limit Value of 0.2 mg/m^3.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Uranium or insoluble compounds can affect the body if they are inhaled or if they come in contact with the eyes or skin. They can also affect the body if they are swallowed.

- **Effects of overexposure**

Exposure to insoluble uranium compounds has been reported to cause an increase in cancer of the lymphatic and blood-forming tissues in man. Prolonged contact with the skin might cause radiation damage to the skin. Prolonged inhalation of insoluble uranium compounds has caused damage to the lungs of animals.

- **Reporting signs and symptoms**

A physician should be contacted if anyone develops any signs or symptoms and suspects that they are caused by exposure to uranium or insoluble compounds.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to uranium or insoluble compounds at potentially hazardous levels:

1. Initial Medical Examination:

—A complete history and physical examination: The purpose is to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. Exami-

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These recommendations reflect good industrial hygiene and medical surveillance practices and their implementation will assist in achieving an effective occupational health program. However, they may not be sufficient to achieve compliance with all requirements of OSHA regulations.

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nation of the respiratory system, blood, and lymphatic system should be stressed. The skin should be examined for evidence of chronic disorders.

—A complete blood count: Since uranium is deposited in the bone and is an alpha particle emitter, the function of the bone marrow is at risk. A complete blood count should be performed including a red cell count, a white cell count, a differential count of a stained smear, as well as hemoglobin and hematocrit.

—14" x 17" chest roentgenogram: Uranium or insoluble compounds cause lung damage in animals. Surveillance of the lungs is indicated.

—Urinalysis: Although not reported with insoluble uranium compounds, kidney damage has been reported due to uranium exposure. A urinalysis should be performed, including at a minimum specific gravity, albumin, glucose, and a microscopic on centrifuged sediment.

2. Periodic Medical Examination: The aforementioned medical examinations should be repeated on an annual basis. In addition, a determination of urinary uranium levels should be performed at any time overexposure is suspected or signs and symptoms of toxicity occur.

- **Summary of toxicology**

Insoluble compounds of uranium are less toxic than the soluble compounds. They are weakly radioactive and are principally alpha particle emitters; fibrotic changes have been observed in the lungs of animals after prolonged inhalation exposure, although radiation effects (other than possible carcinogenesis from absorbed uranium) have not been observed in humans. Both feeding and percutaneous toxicity studies on animals indicate that the insoluble uranium compounds are less toxic than the soluble compounds. Repeated exposures of three animal species to uranium dioxide dust at a concentration of 5 mg uranium/m^3 for periods up to 5 years resulted in no kidney injury; over 90% of the uranium found in the body was in the lungs and tracheobronchial lymph nodes (TLN). Fibrotic changes suggestive of radiation injury were seen occasionally in the TLN of dogs and monkeys and in the lungs of monkeys after exposure periods longer than 3 years; the estimated alpha dose to tissues was greater than 500 rads for lungs and 7000 rads for TLN. Rats injected with metallic uranium in the femoral marrow and in the chest wall developed sarcomata; whether this was due to metallocarcinogenic or radiocarcinogenic action could not be determined. The increased incidence of lung cancer reported among uranium miners is probably the result of exposure to radon gas and its particulate daughters, rather than to uranium dust. In a group of uranium mill workers, there was an excess of deaths from malignant disease of lymphatic and hematopoietic tissue; data from animal experiments suggested that this excess may have resulted from irradiation of lymph nodes by thorium-230, a disintegration product of uranium. Some absorbed uranium is deposited in bone; a potential risk of radiation effects on bone marrow has been postulated, but extensive clinical studies on exposed workers have disclosed no hematologic abnormalities. No evidence of chronic toxicity, either chemical or radiation, was observed for any uranium compound in the milling process during the first 6 years of the atomic energy program; all exposed workers were under very close medical surveillance. Prolonged skin contact with uranium compounds should be avoided because of potential radiation damage to basal cells; dermatitis has occurred as a result of handling uranium tetrafluoride.

CHEMICAL AND PHYSICAL PROPERTIES

- **Physical data—Metallic uranium**
  1. Molecular weight: 238.03
  2. Boiling point (760 mm Hg): 3818 C (6904 F)
  3. Specific gravity (water = 1): 18.95
  4. Vapor density (air = 1 at boiling point of metallic uranium): Not applicable
  5. Melting point: 1133 C (2071 F)
  6. Vapor pressure at 20 C (68 F): Essentially zero
  7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
  8. Evaporation rate (butyl acetate = 1): Not applicable
- **Physical data—Uranium octaoxide**
  1. Molecular weight: 842.1
  2. Boiling point (760 mm Hg): Decomposes at 1300 C (2372 F)
  3. Specific gravity (water = 1): 7.31
  4. Vapor density (air = 1 at boiling point of uranium octaoxide): Not applicable
  5. Melting point: 1300 C (2372 F) (decomposes)
  6. Vapor pressure at 20 C (68 F): Essentially zero
  7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
  8. Evaporation rate (butyl acetate = 1):
- **Physical data—Uranium tetrafluoride**
  1. Molecular weight: 314
  2. Boiling point (760 mm Hg): 1417 C (2582 F) (sublimes)
  3. Specific gravity (water = 1): 6.7
  4. Vapor density (air = 1 at boiling point of uranium tetrafluoride): Not applicable
  5. Melting point: 969 C (1776 F)
  6. Vapor pressure at 20 C (68 F): Essentially zero
  7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble
  8. Evaporation rate (butyl acetate = 1): Not applicable
- **Physical data—Uranium hydride**
  1. Molecular weight: 241
  2. Boiling point (760 mm Hg): Decomposes
  3. Specific gravity (water = 1): Data not available
  4. Vapor density (air = 1 at boiling point of uranium hydride): Not applicable
  5. Melting point: Decomposes
  6. Vapor pressure at 20 C (68 F): Essentially zero, except for decomposition products

7. Solubility in water, g/100 g water at 20 C (68 F): Insoluble

8. Evaporation rate (butyl acetate = 1): Not applicable

• **Reactivity**

1. Conditions contributing to instability: Heat (uranium hydride). Uranium turnings and fines stored out-of-doors in closed containers under water or water-soluble oil will partially convert into the hydride and eventually ignite during hot weather.

2. Incompatibilities: Contact of uranium with carbon dioxide, carbon tetrachloride, or nitric acid will cause fires or explosions. Contact of uranium hydride with strong oxidizers may cause fires and explosions. Contact of uranium hydride with water will form flammable and explosive hydrogen gas. Contact of uranium hydride with halogenated hydrocarbons can be violent.

3. Hazardous decomposition products: Toxic gases and vapors (such as hydrogen fluoride and carbon monoxide) may be released when uranium or insoluble compounds decompose.

4. Special precautions: None

• **Flammability**

1. Flash point: Not applicable

2. Minimum ignition temperature: Uranium: 20 C (68 F) (cloud); 100 C (212 F) (layer); Uranium hydride: 20 C (68 F) (cloud); 20 C (68 F) (layer)

3. Minimum explosive concentration: 60 grams/m^3

4. Extinguishant: Dry powder, dry sand, graphite

• **Warning properties**

According to Grant, "several uranium compounds tested by dropping on the eyes of rabbits, guinea pigs, and rats have been found to cause severe eye damage as well as systemic poisoning. Compounds which have been found to cause moderately severe injury of the eyes are . . . uranium tetrafluoride, . . . uranium trioxide, uranium dioxide, and uranium peroxide . . . . The mildest damage was caused by the various uranium oxides."

MONITORING AND MEASUREMENT PROCEDURES

• **General**

Measurements to determine employee exposure are best taken so that the average eight-hour exposure is based on a single eight-hour sample or on two four-hour samples. Several short-time interval samples (up to 30 minutes) may also be used to determine the average exposure level. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee).

• **Method**

At the time of publication of this guideline, no measurement method for uranium or insoluble compounds had been published by NIOSH.

RESPIRATORS

• Good industrial hygiene practices recommend that engineering controls be used to reduce environmental concentrations to the permissible exposure level. However, there are some exceptions where respirators may be used to control exposure. Respirators may be used when engineering and work practice controls are not technically feasible, when such controls are in the process of being installed, or when they fail and need to be supplemented. Respirators may also be used for operations which require entry into tanks or closed vessels, and in emergency situations. If the use of respirators is necessary, the only respirators permitted are those that have been approved by the Mine Safety and Health Administration (formerly Mining Enforcement and Safety Administration) or by the National Institute for Occupational Safety and Health.

• In addition to respirator selection, a complete respiratory protection program should be instituted which includes regular training, maintenance, inspection, cleaning, and evaluation.

PERSONAL PROTECTIVE EQUIPMENT

• Employees should be provided with and required to use impervious clothing, gloves, face shields (eight-inch minimum), and other appropriate protective clothing necessary to prevent repeated or prolonged skin contact with solids or liquids containing uranium or insoluble compounds.

• If employees' clothing may have become contaminated with solids or liquids containing uranium or insoluble compounds, employees should change into uncontaminated clothing before leaving the work premises.

• Clothing contaminated with uranium or insoluble compounds should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of uranium or insoluble compounds from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the uranium or insoluble compounds, the person performing the operation should be informed of the hazardous properties of these substances.

• Non-impervious clothing which becomes contaminated with uranium or insoluble compounds should be removed promptly and not reworn until the uranium or insoluble compounds are removed from the clothing.

• Employees should be provided with and required to use dust- and splash-proof safety goggles where there is any possibility of solids or liquids containing uranium or insoluble compounds contacting the eyes.

• Where there is any possibility that employees' eyes may be exposed to solids or liquids containing uranium or insoluble compounds, an eye-wash fountain should be provided within the immediate work area for emergency use.

SANITATION

- Skin that becomes contaminated with uranium or insoluble compounds should be promptly washed or showered with soap or mild detergent and water to remove any uranium or insoluble compounds.
- Eating and smoking should not be permitted in areas where solids or liquids containing uranium or insoluble compounds are handled, processed, or stored.
- Employees who handle solids or liquids containing uranium or insoluble compounds should wash their hands thoroughly with soap or mild detergent and water before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

The following list includes some common operations in which exposure to uranium or insoluble compounds may occur and control methods which may be effective in each case:

Operation	Controls
Liberation from mining, grinding, and milling of ores	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment
Use of insoluble compounds as chemical intermediates in preparation of uranium compounds; use for nuclear technology	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in nuclear reactors as fuel and to pack nuclear fuel rods	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment
Liberation from burning of uranium metal chips and smelting operations	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment
Use in ceramics industry for pigments, coloring porcelain, painting on porcelain, and enamelling	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment
Use as catalysts for many reactions; in production of fluorescent glass	Process enclosure; local exhaust ventilation; general dilution ventilation; personal protective equipment

EMERGENCY FIRST AID PROCEDURES

In the event of an emergency, institute first aid procedures and send for first aid or medical assistance.

- **Eye Exposure**

If solids or liquids containing uranium or insoluble compounds get into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. If irritation is present after washing, get medical attention. Contact lenses should not be worn when working with these chemicals.

- **Skin Exposure**

If solids or liquids containing uranium or insoluble compounds get on the skin, promptly wash the contaminated skin using soap or mild detergent and water. If solids or liquids containing uranium or insoluble compounds penetrate through the clothing, remove the clothing immediately and wash the skin using soap or mild detergent and water. If irritation is present after washing, get medical attention.

- **Breathing**

If a person breathes in large amounts of uranium or insoluble compounds, move the exposed person to fresh air at once. If breathing has stopped, perform artificial respiration. Keep the affected person warm and at rest. Get medical attention as soon as possible.

- **Swallowing**

When solids or liquids containing uranium or insoluble compounds have been swallowed, give the person large quantities of water immediately. After the water has been swallowed, try to get the person to vomit by having him touch the back of his throat with his finger. Do not make an unconscious person vomit. Get medical attention immediately.

- **Rescue**

Move the affected person from the hazardous exposure. If the exposed person has been overcome, notify someone else and 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.

SPILL PROCEDURES

- Persons not wearing protective equipment and clothing should be restricted from areas of spills until cleanup has been completed.
- If uranium or insoluble compounds are spilled, the following steps should be taken:

1. Ventilate area of spill.

2. Collect spilled material in the most convenient and safe manner and deposit in sealed containers for reclamation. Liquid containing uranium or insoluble compounds should be absorbed in vermiculite, dry sand, earth, or a similar material. Uranium chips or turnings which are spilled should be covered with oil.

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RESPIRATORY PROTECTION FOR URANIUM AND INSOLUBLE COMPOUNDS (AS URANIUM)

Condition	Minimum Respiratory Protection* Required Above 0.25 mg/m³
Particulate Concentration	
2.5 mg/m³ or less	Any fume respirator or high efficiency particulate filter respirator approved for radon daughters or radionuclides. Any supplied-air respirator. Any self-contained breathing apparatus.
12.5 mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
30 mg/m³ or less	A powered air-purifying respirator with a full facepiece and a high efficiency particulate filter. A Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, helmet, or hood operated in continuous-flow mode.
Greater than 30 mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.
Escape	A high efficiency particulate filter respirator. Any escape self-contained breathing apparatus.

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