Occupational Health Guideline for Soluble Uranium 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 soluble uranium compounds. Physical and chemical properties of several specific compounds are provided for illustrative purposes.

SUBSTANCE IDENTIFICATION

Uranium hexafluoride

- Formula: UF_6
- Synonyms: None
- Appearance: Yellow, deliquescent solid.

Uranyl nitrate

- Formula: $UO_2(NO_3)_2$-$6H_2O$
- Synonyms: Uranium nitrate
- Appearance and odor: Yellow, odorless solid.

Uranyl sulfate

- Formula: UO_2SO_4-$3H_2O$
- Synonyms: None
- Appearance and odor: Yellow-green, odorless solid.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for soluble uranium compounds is 0.05 milligram of soluble uranium 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 soluble uranium compounds a Threshold Limit Value of 0.2 mg/m^3.

HEALTH HAZARD INFORMATION

- **Routes of exposure**

Soluble uranium 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**

1. Short-term Exposure: Soluble uranium compounds may cause irritation of the eyes with damage, lung damage, and kidney damage.

2. Long-term Exposure: Repeated or prolonged skin exposure to soluble uranium compounds may cause radiation damage to the skin. Exposure to soluble uranium compounds has been reported to cause an increase in cancer of the lymphatic and blood-forming tissues of man.

3. 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 soluble uranium compounds.

- **Recommended medical surveillance**

The following medical procedures should be made available to each employee who is exposed to soluble uranium 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. Examination of the respiratory system, blood, liver, lymphatic system, and kidneys should be stressed. The skin should be examined for evidence of chronic disorders.

—Urinalysis: Since kidney damage has been observed in humans exposed to uranium, a urinalysis should be performed, including at a minimum specific gravity, albumin, glucose, and a microscopic on centrifuged sediment.

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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Public Health Service Centers for Disease Control
National Institute for Occupational Safety and Health

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

—A complete blood count: Since uranium is deposited in the bone and is an alpha-particle emitter, the function of the bone marrow should be monitored. 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.

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**

Soluble compounds of uranium as dust or mist are respiratory irritants and are toxic to the kidneys; uranium is weakly radioactive and emits alpha particles. Animals repeatedly exposed to dusts of soluble uranium compounds in concentrations from 3 to 20 mg/m^3 died of pulmonary and renal damage; both feeding and percutaneous toxicity studies on animals indicate that the more soluble compounds are the most toxic. In animals, effects on the liver are a consequence of the acidosis and azotemia induced by renal dysfunction. 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. Accidental exposure of workers to a mixture of uranium hexafluoride, uranium oxyfluoride, hydrofluoric acid, and live steam caused lacrimation, conjunctivitis, shortness of breath, paroxysmal cough, rales in the chest, nausea, vomiting, skin burns, transitory albuminuria, and elevation of blood urea nitrogen. The persons having the greatest exposure showed the highest urinary uranium levels; in addition, their urinary abnormalities were the most severe; these were albuminuria plus red cells and casts in the urinary sediment. Blood urea nitrogen remained elevated for several weeks. The injurious effects observed on the skin, eyes, and respiratory tract apparently were caused by the irritant action of the fluoride ion, whereas the uranium was responsible for the transient renal changes. No evidence of chronic toxicity, either chemical or radiation, was observed for any uranium compound during the first 6 years of the atomic energy program; all exposed workers were under very close medical surveillance. Soluble uranium compounds tested on the eyes of animals caused severe eye damage as well as systemic poisoning; the anion and its hydrolysis products determine the degree of injury. A hot nitric acid solution of uranyl nitrate spilled on the skin caused skin burns, nephritis, and encephalopathy. 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 hexafluoride.

CHEMICAL AND PHYSICAL PROPERTIES

• **Physical data—Uranium hexafluoride**

1. Molecular weight: 352
2. Boiling point (760 mm Hg): 56 C (133 F) (sublimes)
3. Specific gravity (water = 1): 4.68
4. Vapor density (air = 1 at boiling point of uranium hexafluoride): 12 (approximately)
5. Melting point: 65 C (149 F)
6. Vapor pressure at 20 C (68 F): 109 mm Hg
7. Solubility in water, g/100 g water at 20 C (68 F): Reacts
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Uranyl nitrate**

1. Molecular weight: 502.1
2. Boiling point (760 mm Hg): 118 C (244 F)
3. Specific gravity (water = 1): 2.8
4. Vapor density (air = 1 at boiling point of uranyl nitrate): Not applicable
5. Melting point: 60.2 C (140 F) (loses water)
6. Vapor pressure at 20 C (68 F): None, except water of crystallization
7. Solubility in water, g/100 g water at 20 C (68 F): 67
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Physical data—Uranyl sulfate**

1. Molecular weight: 420.1
2. Boiling point (760 mm Hg): Decomposes at 100 C (212 F) (loses water)
3. Specific gravity (water = 1): 3.3
4. Vapor density (air = 1 at boiling point of uranyl sulfate): Not applicable
5. Melting point: 100 C (212 F) (loses water)
6. Vapor pressure at 20 C (68 F): None, except water of crystallization
7. Solubility in water, g/100 g water at 20 C (68 F): 70
8. Evaporation rate (butyl acetate = 1): Not applicable

• **Reactivity**

1. Conditions contributing to instability: None hazardous
2. Incompatibilities: Contact of uranyl nitrate with combustible material may cause fires and explosions. Uranium hexafluoride reacts with water to form hydrofluoric acid, a very corrosive substance.
3. Hazardous decomposition products: Toxic gases

and vapors (such as oxides of nitrogen and hydrofluoric acid) may be released in a fire involving soluble uranium compounds.

4. Special precautions: Uranium hexafluoride will attack some forms of plastics, rubber, and coatings.

- **Flammability**

1. Not combustible

- **Warning properties**

Grant states that "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 pentachloride, uranium tetrachloride, uranyl nitrate, (and) uranyl fluoride .... Application of 1 mg of solid uranium pentachloride to the eyes of rabbits caused the most severe necrosis of conjunctivae and lids, and perforating ulceration of the cornea. The other chlorides and the nitrate were also severely damaging."

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 soluble uranium 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 any possibility of skin contact with solids or liquids containing uranium hexafluoride.
- 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 soluble uranium compounds.
- If employees' clothing has had any possibility of being contaminated with uranium hexafluoride, or if employees' clothing may have become contaminated with other soluble uranium compounds, employees should change into uncontaminated clothing before leaving the work premises.
- Clothing which has had any possibility of being contaminated with uranium hexafluoride or clothing contaminated with other soluble uranium compounds should be placed in closed containers for storage until it can be discarded or until provision is made for the removal of soluble uranium compounds from the clothing. If the clothing is to be laundered or otherwise cleaned to remove the soluble uranium compounds, the person performing the operation should be informed of soluble uranium compounds's hazardous properties.
- Where there is any possibility of exposure of an employee's body to solids or liquids containing uranium hexafluoride, facilities for quick drenching of the body should be provided within the immediate work area for emergency use.
- Non-impervious clothing which becomes contaminated with uranium hexafluoride should be removed immediately and non-impervious clothing which becomes contaminated with other soluble uranium compounds should be removed promptly and not reworn until the soluble uranium 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 soluble uranium compounds contacting the eyes.
- Where there is any possibility that employees' eyes may be exposed to solids or liquids containing soluble uranium compounds, an eye-wash fountain should be provided within the immediate work area for emergency use.

SANITATION

- Skin that becomes contaminated with uranium hexafluoride should be immediately washed or showered and skin that becomes contaminated with soluble uranium compounds should be promptly washed or showered to remove any soluble uranium compounds.

• Workers subject to skin contact with solids or liquids containing uranium hexafluoride should wash any areas of the body which may have contacted uranium hexafluoride at the end of each work day.
• Eating and smoking should not be permitted in areas where solids or liquids containing soluble uranium compounds are handled, processed, or stored.
• Employees who handle solids or liquids containing soluble uranium compounds should wash their hands thoroughly before eating, smoking, or using toilet facilities.

COMMON OPERATIONS AND CONTROLS

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

Operation	Controls
Liberation during mining and purification of ore; during enrichment of elemental uranium; from recovery of process waste	Process enclosure; local exhaust ventilation; personal protective equipment
Use in fabrication of materials for military use and power plants	Process enclosure; local exhaust ventilation; personal protective equipment
Use as analytical reagents; use in chemical synthesis; use in manufacture of dyestuff intermediates and preparation of oxides	Process enclosure; local exhaust ventilation; personal protective equipment
Use in manufacture of ceramic glazes; use as photographic intensifiers and in x-ray technology; in miccellaneous uses for textile printing, tobacco printing, antifungal agents, electroplating additives, and bacterial oxidants	Process enclosure; local exhaust 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 soluble uranium compounds get into the eyes, wash eyes immediately with large amounts of water, lifting the lower and upper lids occasionally. Get medical attention immediately. Contact lenses should not be worn when working with these chemicals.
• **Skin Exposure**
If solids or liquids containing soluble uranium compounds get on the skin, immediately flush the contaminated skin with water. If solids or liquids containing soluble uranium compounds penetrate through the clothing, remove the clothing immediately and flush the skin with water. If irritation is present after washing, get medical attention.
• **Breathing**
If a person breathes in large amounts of soluble uranium 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 soluble uranium 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 soluble uranium 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 or for disposal in a secured sanitary landfill. Liquid containing soluble uranium compounds should be absorbed in vermiculite, dry sand, earth, or a similar material.

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RESPIRATORY PROTECTION FOR URANIUM SOLUBLE COMPOUNDS (AS URANIUM)

Condition	Minimum Respiratory Protection* Required Above 0.05 mg/m³
Particulate Concentration	
2.5 mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece (not applicable for uranium halides). A chemical cartridge respirator with a full facepiece, acid gas cartridge(s), and high efficiency particulate filter (for uranium halides only). A gas mask with a chin-style or a front- or back-mounted acid gas canister and high efficiency particulate filter (for uranium halides only). Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
20 mg/m³ or less	A powered air-purifying respirator with a full facepiece and a high efficiency particulate filter (not applicable for uranium halides). 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 20 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 with acid gas cartridge for uranium halides. Any gas mask providing protection against acid gases and particulates (for uranium halides only). Any escape self-contained breathing apparatus.

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