

Development of the AEGl and ERPG Values of Uranium Hexafluoride (UF₆)

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Outline

- Characteristics of UF₆
- General toxicological issues for assessing UF₆
- Animal toxicity of UF₆
- Human toxicity of UF₆
- Human acute toxicity for 1-h exposures
- Development of AEGL-1, -2, and -3 values
- Development of ERPG-1, -2, and -3 values
- Summary

Uranium Hexafluoride, UF₆

CAS Reg. No. 7783-81-5

- Produced by fluorination of U₃O₈ ore.
- An odorless, colorless (25° C), and volatile solid (56.4° C).
- A strategic chemical: energy production and national security.
- Used for uranium enrichment (0.72% to 2 - 4% or “highly enriched”) by gaseous diffusion and gas centrifugation processes.
- Soluble in CCl₄ and CHCl₃.
- Hydrolyzes rapidly on contact with water.



General Toxicological Issues for UF₆

- **Chemical toxicity:**

- Mixtures of HF and UO₂F₂.
- Effects of HF component are pulmonary irritation, corrosion, or edema. Higher concentration can lead to death.
- Effects of Uranium component are renal injury, glomerular and tubular wall degeneration, impaired renal functions.

- **Radiological toxicity:**

- Mixtures of 0.01% U-234, 0.72% U-235, and 99.27% U-238.
- Emits of α , β , and γ radiation.
- Health hazard depends on the degree of enrichment.
- Risk from acute radiological exposure is negligible when compared to that from chemical toxicity.

Animal Toxicity

- **Lethality:**
 - Rats, mice, and guinea pigs all were exposed to UF_6 at 942, 1083 or 2284 mg/m^3 for 10-min in a chamber and observed up to 30 days.
 - Deaths occurring within 48-h of exposure to HF; after 48-h deaths were attributed to uranium toxicity or combination of HF and uranium toxicity.
 - Surviving animals showed respiratory tract irritation, pulmonary edema, and renal lesions.
 - Rats, LC_{50} is 1095 mg/m^3 (1-h exposure). **AEGL-3**
 - Dogs administered UF_6 intratracheally, at 192 to 284 mg/m^3 for 30-min to 1-h, showed no respiratory or pulmonary effects but renal injury. **AEGL-2**
- **Genotoxicity, Developmental and Reproductive toxicity:** No data available.
- **Carcinogenicity:** No evidence in dogs and rats at 0.05 mg/m^3 for 1-y.

Human Toxicity

- **Lethality** (two case reports)
 - ❖ Manhattan Engineering District Pilot Plant, Philadelphia, PA (1944). Released from ruptured cylinder 182 kg of UF_6 formed dense cloud and dispersed rapidly.
 - 20 workers exposed (2 deaths and several recoverable injuries).
 - ❖ Kerr-McGee Facility, Gore, OK (1986). Released from ruptured overloaded cylinder 6700 kg of UF_6 , formed white cloud, pushed by wind to cover a large area.
 - 42 workers on-site exposed (1 death and several recoverable injuries).
- **Genotoxicity, Developmental and Reproductive toxicity:** No data available.
- **Carcinogenicity:** Limited data. No findings from a 38-year follow up examination of two workers seriously injured in an accidental exposure in 1944. Lung deposition estimated at 59 to 74 mg of UF_6 .

Human Acute Toxicity for 1-h Exposures *

(Just, 1984; and Just and Emler, 1984)

Exposed UF ₆ , mg/m ₃	Exposed UF ₆ , ppm	Effect	Absorbed dose, mg-UF ₆ /kg b.w.
<9.6	<38.4	No effect	0.026
9.6-18.5	38.4-74	Mild health effects	NA
19.5	78	Renal injury	0.051
352	1408	10% lethality	NA
862	3448	50% lethality	2.47

•**ICRP** model presumes a **70 kg** human body weight, breathing rate **7.5 L/min**, and absorption factor of **0.43**

Development of AEGL-1

- The key study is Lunds et al., (1997, 1999), involving exposure of exercising human subjects to several concentrations.
- The estimated threshold for inflammation was 3 ppm for 1-h, no significant sensory irritation was observed.
- An uncertainty factor of 3 was applied to account for human susceptibility.
- No time scaling was applied.
- A stoichiometric adjustment of 4 was used. Four moles of HF are produced from hydrolysis of one mole of UF₆.



$$\text{AEGL-1}_{\text{UF}_6} = \text{AEGL-1}_{\text{HF}/4} = 1 \text{ ppm} / 4 = 0.25 \text{ ppm}$$

$$\text{Conversion from ppm to mg/m}^3 = 0.25 \times 14.4 = 3.6 \text{ mg/m}^3$$

Development of ERPG-1

- The estimated no effect exposure level for uranium is 9.6 mg-UF₆/m³. (Just, 1984; Just and Emler, 1984).
- No tissue damage occurred in workers exposed to air concentrations < 74 mg-UF₆/m³.
- 5 mg-UF₆/m³ was set by the ERP Committee as a Level 1 value.
- Exposure up to one hour without experiencing other than mild, transient adverse health effects or clearly defined objectionable odor.

Final AEGL-1 and ERPG-1

10-min	30-min	1-h	4-h	8-h
3.6 mg/m ³	3.6	3.6	NR	NR

NR: Not recommended. Values are greater than AEGL-2.

The ERPG -1 is 5 mg/m³ for up to 1-h.

Development of AEGL-2

- The key study is Morrow et al., (1982), dog, inhalation exposure to 192 to 284 mg/m³ for 30-min to 1-h exposure.
- The primary effect is kidney injury.
- Uncertainty factors for a total of 10 were applied (inter- and intraspecies, 3 each).
- Time scaling was applied using $C^n \times t = K$ as follows:
 - For 10- and 30-min, where $C = 192$; $n = 3$; $t = 0.5$; thus
 $K = 3,538,944 \text{ mg/m}^3\text{-h}$
 - For 1-, 4-, and 8-h, where $C = 192$; $n = 1$; $t = 0.5$; thus
 $K = 96 \text{ mg/m}^3\text{-h}$
- These values are supported by a similar study of exposing dogs to UO₂F₂ at 200 to 270 mg/m³ for 30-min to 2.5-h and similar renal pathology was observed (Morrow et al., 1982).

Development of ERPG-2

- Renal toxicity is the primary effect of concern.
- Severe exposures will produce pulmonary injury beginning with edema, fibrosis and respiratory failure.
- In a study of renal toxicity, initial effects begin at 17.6 mg-UF₆/m³ (Morrow et al., 1982).
- 15 mg-UF₆/m³ was set by the ERP Committee as a Level 2 value.
- No irreversible effects or impairment of ability to take protective action should occur at this Level.

Final AEGL-2 and ERPG-2

10-min	30-min	1-h	4-h	8-h
27.7 mg/m ³	19.2	9.6	2.4	1.2

The ERPG -2 is 15 mg/m³ for up to 1-h.

Developing AEGL-3

- Key study is Leach et al., (1984), rats, 1-h exposure, LC₅₀, 1095 mg/m³.
- The estimated 1-h threshold, 1/3 of LC₅₀, 365 mg/m³.
- The uncertain factors represent a total of 10 as follows:
 - ❖ Interspecies: 3 steep dose response, limit variation.
 - ❖ Intraspecies: 3 for sensitive population.
- The time scaling using $C^n \times t = K$, where $n = 1$ was applied as follows;

$$C = 365; t = 1; \text{ thus } K = 365 \text{ mg/m}^3\text{-h}$$

Development of ERPG-3

- Very high exposures are necessary for injury and lethality due to HF release when UF₆ is hydrolyzed.
- The 1-hr LC₁₀ is 400 mg-UF₆/m³. (Leach, 1984; Leach et al., 1984)
- The 1-hr LC_{0.01} is 45 mg-UF₆/m³ and/or its hydrolysis products.
- 30 mg-UF₆/m³ was set as the ERPG-3.
- Life-threatening health effects are not expected at this Level.

Final AEGL-3 and ERPG-3

10-min	30-min	1-h	4-h	8-h
216 mg/m ³	73	36.5	9.0	4.5

The ERPG -3 is 30 mg/m³ for up to 1-h.

Summary

- There are currently 24 Final and 65 Interim AEGLs, and 125 ERPGs are available for PAC in DOE sites.

Uranium hexafluoride, UF_6
(mg/m^3)

PAC priority	Level-1	Level-2	Level-3
AEGLs	3.6	9.6	36
ERPGs	5	15	30