

## ARSENIC SURVEILLANCE PROGRAM

*NASA Lewis Research Center  
Occupational Medicine Service*

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### Background

There are three basic forms of arsenic; salts, oxides, and arsine gas, all of which are toxic to humans. Chronic inhalation of inorganic arsenic compounds is the most common cause of industrial arsenic poisoning; however, arsenic also enters the body via ingestion and absorption through the skin. Trivalent arsenic (arsenite) is more toxic than pentavalent arsenic (arsenate) by several orders of magnitude, yet the arsenates are better absorbed and may be converted to arsenites once in the body.

Arsenicals are found in pesticides, herbicides, rat poisons, semiconductors, and wood preservatives, and are often by-products of some industrial metallurgical applications (e.g., copper smelting). Additionally, arsenic compounds have been found in seafood and as an ingredient in some homeopathic medications. Arsenic binds with the sulfhydryl groups of the body's proteins, interfering with the ability of various enzymes to catalyze crucial cell metabolism. Arsenic has also been shown to increase chromosomal breakage and therefore may be teratogenic, mutagenic, and carcinogenic.

Acute clinical symptoms from arsenic exposure can vary widely depending on the type and chemical state of the arsenic involved, age and physical condition of the subject, and the duration and dose of the exposure. Symptoms of acute poisoning may occur within minutes or be delayed for several hours. Initially, acute exposure to arsenic can be irritating to both the skin and mucous membranes of the respiratory system and gastrointestinal tract. When there is a primary inhalation of an arsenic-containing substance, much of the substance is actually ingested as accumulated inhaled material in the mucous secretions of the upper respiratory system are swallowed. Arsenicals can cause damage to capillary walls rendering them quite friable. Inhalation can lead to nosebleeds and perforation of the nasal sputum as well as causing small hemorrhages on the mucous membranes of the entire respiratory tree and gastrointestinal tract, and causing hemorrhages directly on exposed skin. Symptoms of nausea, vomiting (often hematemesis), colicky abdominal pain, diarrhea (often bloody), thirst, dizziness, muscle cramps, and burning of the mouth result from inflammation of the gastrointestinal tract

mucosa. Similar damage can occur to the brain's capillaries if a large enough dose of arsenic is ingested or inhaled, resulting in peri-capillary edema, intraluminal clotting and, eventually, infarct. The heart can be affected acutely, as demonstrated by electrocardiogram changes which principally include tenting and elevation of the T-wave, and can progress with chronic exposure onto QT prolongation. Death is frequently rapid and occurs through disseminated central nervous system damage, marked weakness and muscle paralysis, liver and kidney damage, and vasomotor collapse.

Arsine gas, unlike arsenic, preferentially binds to hemoglobin causing massive hemolysis, hemoglobinuria, jaundice, and subsequent renal failure. Inhalation of very small quantities of arsine gas can be rapidly fatal. For example, inhaling 250 ppm (parts per million) of arsine gas is instantly fatal, while exposure to 25-50 ppm over 30 minutes is lethal.

About five weeks after an acute exposure to arsenic, the **Mees line**, a transverse white line in the nails, 1 to 2 mm in width, becomes visible above the cuticle. The lines advance at about 1 mm per week, allowing estimation of the time of acute exposure.

Chronic exposure to low levels of arsenic compounds may result in small, superficial ulcers in the gastrointestinal tract or affect other mucous membranes, causing keratoconjunctivitis, corneal necrosis, and rhinopharyngeal-tracheobronchitis. Hepatic enlargement, frequently with few liver function abnormalities, has been observed. Peripheral neuritis, in a "stocking glove" distribution, resulting in motor dysfunction and paresthesia can occur. Chronic skin changes are the best recognized result of long-term arsenic exposure, with facial edema, erythema, desquamation, and hyperpigmentation of resultant scars frequent signs. The hyperpigmentation frequently also occurs over the neck, armpits, and nipples. Hyperkeratosis of the palms and soles often are apparent, which can progress occasionally to skin cancers. Painful hot, swollen feet that make walking very difficult are readily diagnosable symptoms of chronic arsenic exposure. Various degrees of bone marrow suppression have been reported, leading to depletion of specific cell lines, or pancytopenia.

Quantitative 24-hour urine collections seem to be the most reliable laboratory measurement of arsenic poisoning. After a single dose of arsenic, most urinary excretion occurs over the first four days, with virtually negligible levels found after the sixth day. The upper limit of normal for a 24-hour urine arsenic is 100  $\mu\text{g}$  (micrograms)/24 hours.

Blood arsenic levels (with normal less than 7  $\mu\text{g}/100$  ml) do not correlate well with chronic exposure, although they may help to confirm diagnosis after an acute exposure. Spot urine arsenic levels have been unreliable and may be falsely elevated after eating seafood, for example, or other arsenic-containing substances. Hair and nail analysis for arsenic is also inconsistent and unreliable.

### **Purpose**

The purpose of the Arsenic Surveillance Program at the NASA Lewis Research Center shall be to:

1. Identify any Lewis employee who is exposed to arsenic above the action level, at the physician's discretion;
2. Educate that employee about the nature of arsenic, the proper use of respiratory protection and protective clothing, and appropriate sanitation practices to be used when handling arsenic-containing substances;
3. Monitor those employees by obtaining an extensive past medical and occupational exposure history, and then perform periodic physical exams with twenty-four (24) hour urine collections for arsenic concentrations to detect early signs and symptoms of arsenic poisoning. When arsenic exposure is anticipated, a baseline physical exam with a 24-hour urine collection for arsenic shall be obtained.

### **Medical Surveillance**

The specifics of the Medical Surveillance Program for Arsenic Exposure at the NASA Lewis Research Center will fulfill the criteria required by OSHA and will incorporate recommendations from NIOSH.

The permissible exposure limit (PEL) for arsenic-containing compounds, as defined by OSHA, are:

Inorganic arsenic	0.010 mg/m <sup>3</sup> (10 µg/m <sup>3</sup> )
Organic arsenic	0.5 mg/m <sup>3</sup> (500 µg/m <sup>3</sup> )
Arsine gas	0.2 mg/m <sup>3</sup> (0.05 ppm)

All PELs are based on an 8-hour TWA. There are no specified STEL or Ceiling Limits for any arsenic-containing substance.

Of greatest clinical importance in an occupational setting are inorganic arsenic substances. The **Action Level (AL)** for inorganic arsenic compounds is defined as 0.005 mg/m<sup>3</sup> (or 5 µg/m<sup>3</sup>). Medical surveillance for arsenic exposure is required for employees exposed at or above the AL for 30 days or more per year.

NASA employees identified by the Office of Environmental Programs as having been exposed to the AL for arsenic will be entered into the medical surveillance program. As soon as possible, these employees will need:

1. **Medical and Work Histories**, with special attention to:
  - dietary habits
  - previous occupational exposures
  - smoking history
  - respiratory symptoms
  - muscle weakness, paresthesia, loss of sensation in extremities
  - skin pigmentations (erythema or hyperpigmentation)
  - skin changes, especially of the palms or soles.
2. **A Complete Physical Exam**, with special attention to:
  - Skin (color, hyperkeratosis, hyperpigmented lesions, fingernails)
  - Mucous membranes (nose, mouth, GI tract, respiratory system)
  - Abdominal exam (tenderness, hepatomegaly)
  - Neurologic exam (strength, sensation, DTRs).
3. **Laboratory Exam**, to include:
  - Chest X-ray
  - CBC with differential
  - Serum chemistries (BUN, Creatinine, LFTs, bilirubin)
  - Urinalysis with microscopy
  - EKG (T-wave abnormalities, QT prolongation)

- Sputum cytology (not recommended in employees under 45 years of age with fewer than 10 years of exposure under the AL)
- Stool guaiac, where acute exposure is suspected
- Abdominal X-rays (KUB), where ingestion is suspected
- 24-hour urine collection for arsenic (normal < 100 µg).

The above evaluation will need to be repeated, at least within seven (7) days if the 24-hour urine arsenic is greater than 100 µg. The frequency at which this exam should be repeated is left to the discretion of the physician, and is based on clinical symptomatology, physical signs, and laboratory abnormalities.

In the event that the Office of Environmental Programs determines that an employee is at an increased risk of arsenic exposure at or above the AL because of the nature of the employee's job or the potential presence of arsenic-containing compounds in the work environment, then that employee shall receive the above evaluation as a baseline exam before potential exposure, followed by annual arsenic surveillance exams, until such time as the OEP determines that the employee is no longer at risk for arsenic exposure.

If there is a risk of any exposure to arsenic in an employee's work environment, regardless if this potential exposure is deemed to be above or below the AL for arsenic as determined by the OEP, then that employee will receive annual arsenic surveillance exams.

Upon retirement or termination of employment, an employee who has been involved in an ongoing arsenic medical surveillance program is entitled to a final arsenic surveillance exam with the appropriate laboratory studies. The Occupational Medicine Service will not continue surveillance of an individual once they have retired or are no longer employed by NASA. During the final examination, recommendations will be given to the individual for continued medical surveillance, if necessary, to be performed by the individual's private physician.

### Summary Table for Frequency of Arsenic Surveillance Exams

Anticipated exposure to arsenic at or above the AL	Baseline arsenic surveillance exam before exposure
Acute exposure to arsenic at or above the PEL	Immediate exam, if possible, with appropriate follow-up as dictated by physical and laboratory findings
Work environment with chronic arsenic levels at or above the AL for 30 days or more per year:	
a. <45 years old with <10 years exposure	Annual Exam
b. $\geq$ 45 years old regardless of duration of exposure	Semi-annual exam (every 6 months)
c. $\geq$ 10 years exposure regardless of age	Semi-annual exam (every 6 months)
Any risk of arsenic exposure	Annual exam

### References

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