

## ToxFAQs: CABS™/Chemical Agent Briefing Sheet

# Arsenic

January 2006

### What is arsenic?

Arsenic is an element that is widely distributed in the earth's crust. Elemental arsenic is a steel grey metal-like material. Arsenic is usually found in the environment combined with other elements, such as oxygen, chlorine, and sulfur. It is released into the air by volcanoes, through weathering of arsenic-containing minerals and ores, especially near geothermal activity, and by commercial or industrial processes. In industry, arsenic is a by-product of the smelting process for many metal ores, including lead, gold, zinc, cobalt, and nickel.

### What are the forms of arsenic?

Arsenic is found in two forms:

- **Inorganic:** Combined with elements such as oxygen, chlorine, and sulfur
- **Organic:** Combined with carbon and hydrogen

The inorganic forms of arsenic are more toxic than the organic ones. The table below lists examples of the different forms of arsenic.

Common valence states	As <sup>0</sup>	metalloid arsenic
	As <sup>3+</sup>	such as arsenites
	As <sup>5+</sup>	such as arsenates
	As <sup>3-</sup>	such as arsine gas
Examples of organic arsenicals	(CH <sub>3</sub> ) <sub>2</sub> AsO(OH)	cacodylic acid (dimethylarsinic acid)
	CH <sub>3</sub> AsO(ONa) <sub>2</sub>	disodium methylarsenate (DSMA)
	C <sub>7</sub> H <sub>9</sub> AsN <sub>2</sub> O <sub>4</sub>	carbasone
Examples of inorganic arsenicals	H <sub>3</sub> AsO <sub>4</sub>	arsenic acid
	Na <sub>2</sub> HAsO <sub>4</sub>	disodium arsenate
	NaAsO <sub>2</sub>	sodium arsenite

## ToxFAQs Chemical Agent Briefing Sheet (CABS): Arsenic

### What are common products and uses of arsenic?

The table below list common products and uses of arsenic.

<b>Commercial products</b>	<ul style="list-style-type: none"><li>• antifouling paints</li><li>• cattle and sheep dips</li><li>• cotton desiccants</li><li>• fire salts (multicolored flame)</li><li>• fungicides</li><li>• herbicides (weed killers and defoliants)</li><li>• insecticides</li><li>• leaded gasoline</li><li>• paints and pigments</li><li>• wood preservatives</li></ul>
<b>Industrial processes</b>	<ul style="list-style-type: none"><li>• bronze plating</li><li>• clarifying glass and ceramics</li><li>• electronics manufacturing (microwave devices, lasers, light-emitting diodes, photoelectric cells, and semiconductor devices)</li><li>• hardening metal alloys</li><li>• preserving animal hides</li><li>• purifying industrial gases (removal of sulfur)</li></ul>
<b>Medicines and remedies</b>	<ul style="list-style-type: none"><li>• Antiparasitic drugs (carbasone - <math>C_7H_9AsN_2O_4</math>)</li><li>• Donovan's solution (arsenic triiodide - <math>AsI_3</math>)</li><li>• Folk remedies ("Asiatic pill," kushtay, yellow root)</li><li>• Fowler's solution (1% solution of potassium arsenite – <math>[K_3AsO_3]</math>)</li><li>• Kelp-containing health foods</li><li>• Some naturopathic remedies</li></ul>

### What are the routes of exposure?

The main way people are exposed to arsenic is by eating arsenic-containing food. Exposure to arsenic from air, soil, and water may also occur. The table below lists routes of exposure.

<b>Food/Wine</b>	<ul style="list-style-type: none"><li>• The estimated average daily dietary intake of total arsenic by adults in the United States is 50 milligrams per day.<ul style="list-style-type: none"><li>○ Meat, fish, and poultry account for 80% of dietary arsenic intake.</li><li>○ Fish, seafood, and algae also contain high concentrations of arsenic in the form of arsenobetaine and arsenocholine, sometimes referred to as "fish arsenic."<ul style="list-style-type: none"><li>▪ Fish arsenic has low toxicity to humans and is rapidly excreted in urine.</li></ul></li><li>○ Wine produced in vineyards that were sprayed with arsenic-containing pesticides may have appreciable levels of arsenic.</li></ul></li></ul>
<b>Smoke</b>	<ul style="list-style-type: none"><li>• Smokers may inhale small amounts of arsenic because of past application of</li></ul>

## ToxFAQs Chemical Agent Briefing Sheet (CABS): Arsenic

	arsenic-containing pesticides on tobacco leaves.
<b>Drinking Water</b>	<ul style="list-style-type: none"> <li>• Exposure to arsenic in drinking water is a problem in some regions of the United States, Mexico, India, and regions of Asia.</li> <li>• Well water contaminated by natural sources such as arsenic-containing bedrock has been reported to be the leading cause of arsenic toxicity throughout the world, including areas of the United States.</li> <li>• The areas in the United States with the highest natural groundwater concentrations of arsenic are New England, the Southwest, the Northwest, Alaska, and areas near geothermal activity.</li> <li>• Groundwater may contain elevated concentrations of arsenic due to contamination from runoff of arsenic-containing pesticides from past use.</li> <li>• Arsenic has been detected in both surface water and groundwater, at average concentrations of 40 and 47 parts per billion (ppb), respectively, in about 15% of hazardous waste sites studied by ATSDR.</li> </ul>

### What are possible toxic effects of concern?

Most of the toxic effects arise from exposure to inorganic arsenic. Because it targets a number of metabolic processes, arsenic affects nearly all organ systems of the body.

<b>Cancer</b>	<ul style="list-style-type: none"> <li>• Arsenic is known to cause cancer in humans.</li> <li>• Ingested inorganic arsenic is strongly associated with lung and skin cancers and may cause other cancers in organs such as the bladder, kidneys, and liver.</li> <li>• Skin cancer associated with eating or drinking of inorganic arsenic may take more than 1 year to develop; noncarcinogenic skin effects typically develop weeks or months after exposure.</li> <li>• The number of deaths among workers exposed by inhalation to inorganic arsenic increases with the duration and intensity of exposure.</li> </ul>
<b>Cardiovascular</b>	Acute arsenic poisoning may cause internal bleeding (diffuse capillary leaks) and inflammation of the heart (cardiomyopathy), resulting in shock. Long-term ingestion of arsenic in drinking water has resulted in pronounced changes in blood vessels outside the heart and brain.
<b>Gastrointestinal</b>	Seen primarily after acute and short-term arsenic ingestion.
<b>Kidney effects</b>	Acute poisoning may cause renal failure.
<b>Liver</b>	Eating or drinking of inorganic arsenic may kill liver cells and elevate levels of liver enzymes.
<b>Neurological</b>	Arsenic can destroy a person's nerve cells, leading to nervous system disorders (peripheral neuropathy).
<b>Pulmonary</b>	Lung cancer deaths among exposed workers increase with their duration and intensity of exposure.
<b>Reproductive</b>	Increased frequency of spontaneous abortions and congenital malformations has been linked to arsenic exposure.

## ToxFAQs Chemical Agent Briefing Sheet (CABS): Arsenic

<b>Respiratory</b>	Inhaling high concentrations of arsenic compounds irritates the lining of the nose, throat, and lungs.
<b>Hematologic</b>	Bone marrow depression (an inability to make certain blood cells) may result from arsenic poisoning and may first appear as a shortage of all types of blood cells. Note: Unlike other forms of arsenic, arsine gas causes a hemolytic syndrome (destruction of red blood cells.)
<b>Skin</b>	Pigment changes and thickening of the skin on hands and feet (palmoplantar hyperkeratosis) are characteristic of chronic (long term) arsenic exposure. Skin cancer associated with eating or drinking arsenic may take 30 to 40 years to develop. Noncarcinogenic skin effects typically develop several years after exposure. Skin thickening caused by arsenic may later become malignant.

What are the government guidelines for arsenic exposure?

<b>Air</b>	<p>Arsenic is listed by the U.S. Environmental Protection Agency (EPA) as a hazardous air pollutant (HAP).</p> <ul style="list-style-type: none"> <li>HAPs are substances that may increase mortality or serious illness in humans after significant exposure.</li> </ul> <p>EPA National Emissions Standards for Hazardous Air Pollutants limit emissions of inorganic arsenic from</p> <ul style="list-style-type: none"> <li>primary copper smelters</li> <li>glass-manufacturing plants</li> <li>arsenic plants</li> </ul> <p><b>However, there is no ambient federal air standard for arsenic.</b></p>
<b>Drinking water</b>	<ul style="list-style-type: none"> <li>The EPA Office of Drinking Water has set a maximum contaminant level (MCL) for arsenic in drinking water of <b>10 ppb</b>.</li> <li>The World Health Organization recommends a provisional drinking water guideline of 10 ppb (0.01 mg/L) as a practical limit.</li> </ul>
<b>Food</b>	<p>The U.S. Food and Drug Administration (FDA) has established tolerance levels for arsenic in by-products of animals treated with veterinary drugs. These permissible levels range</p> <ul style="list-style-type: none"> <li>from 0.5 parts per million (ppm) in eggs and uncooked edible tissues of chickens and turkeys to 2 ppm in certain uncooked edible by-products of pigs and others.</li> </ul>
<b>Pesticides</b>	<ul style="list-style-type: none"> <li>EPA began to phase out household ant poisons containing sodium arsenate in 1989 because of the danger of ingestion by small children.</li> <li>EPA also cancelled all registered uses of inorganic arsenic for nonwood preservative purposes.</li> <li>Pressure-treated wood with chromium-copper-arsenic (CCA) has been phased out for residential use.</li> </ul>

## ToxFAQs Chemical Agent Briefing Sheet (CABS): Arsenic

What are the minimum risk levels for arsenic exposure?

ATSDR Minimal Risk Levels (MRLs), December 2005					
Name	Route	Duration	MRL	Factors	Endpoint
Arsenic	Oral	Acute	0.005 mg/kg/day*	10	Gastrointestinal
		Chronic	0.0003 mg/kg/day	3	Dermal

\*Provisional; mg = milligrams; kg = kilograms

What are the most important or common mediating factors?

The factors that determine how severe the health effects are from arsenic exposure include:

- Age of the person exposed (the fetus is the most susceptible)
- Dose
- Duration of exposure
- Genetic susceptibility
- Health of the person exposed
- Nutritional status
- Route of exposure/inhalation, ingestion, dermal contact, etc.

What are the body's defense systems against arsenic?

- Most tissues, except for skin, hair, and nails, rapidly clear organic arsenic.
- Arsenic changes through methylation in the liver to less-toxic metabolites.
- Arsenic is excreted in the urine; most of a single, low-level dose is excreted within a few days after consuming any form of inorganic arsenic.
- Stress proteins are induced by arsenic.

Is there a test to see if my child or I have been exposed to arsenic?

A key laboratory test in recent exposures to arsenic is urinary excretion of inorganic and methylated arsenic metabolites.

Because urinary levels of arsenic may drop rapidly in the first 24 to 48 hours after short-term exposure, the laboratory needs to obtain a urine specimen for arsenic analysis promptly. Depending on the patient's clinical state, tests may include the following:

- CBC with peripheral smear,
- chest radiograph,
- dermatologic consultation,
- electrocardiogram (ECG),
- electrolyte panel with BUN and creatinine,
- liver function tests,
- nerve conduction velocity (if peripheral neurologic symptoms are present),
- neurologic consultation, and
- urinalysis

## ToxFAQs Chemical Agent Briefing Sheet (CABS): Arsenic

Measurement of arsenic levels in hair and nails may be a useful indicator of past or lengthy exposures. Because arsenic may be adsorbed to the external surface, hair and nail samples should be washed before testing.

### Future research needs

<b>Environmental fate</b>	Additional quantitative data on the rates of oxidation, reduction, and biotransformation reactions of arsenic compounds, and how these depend on environmental conditions would help in evaluating and predicting the fate and transport of arsenic at hazardous waste sites and other areas.
<b>Bioavailability from environmental media</b>	Further data would be useful to establish whether arsenic uptake occurs from contact with contaminated soil or water, since these routes near hazardous waste sites may expose humans.
<b>Food chain bioaccumulation</b>	Further research on the uptake of arsenic by plants in a wide range of arsenic-polluted sites (e.g., mining areas, orchards previously treated with lead arsenate) would be valuable in assessing human exposure near such sites from eating vegetables from home gardens.
<b>Exposure levels in environmental media</b>	<ul style="list-style-type: none"> <li>• Additional monitoring studies that include identification of arsenic species would allow more precise estimation of current exposure levels and possible human health risks.</li> <li>• Reliable monitoring data for the levels of arsenic in contaminated media at hazardous waste sites are needed. Information obtained on levels of arsenic in the environment could be used in combination with the known body burdens of arsenic to assess the potential risk of adverse health effects in people living near hazardous waste sites.</li> </ul>
<b>Exposures of children</b>	<ul style="list-style-type: none"> <li>• Additional studies, including investigations of unique pathways for exposures of children and the amount of soil a child ingests, would provide valuable data.</li> <li>• Studies are needed to assess whether children are different in their weight-adjusted intake of arsenic.</li> </ul>

### For more information

<b>ATSDR</b>	<ul style="list-style-type: none"> <li>• Arsenic in private drinking-water wells <a href="http://www.atsdr.cdc.gov/arsenic/arsenic.html">http://www.atsdr.cdc.gov/arsenic/arsenic.html</a></li> <li>• Case Studies in Environmental Medicine (CSEM): Arsenic toxicity <a href="http://www.atsdr.cdc.gov/HEC/CSEM/arsenic/">http://www.atsdr.cdc.gov/HEC/CSEM/arsenic/</a></li> <li>• Interaction profile for arsenic, cadmium, chromium and lead <a href="http://www.atsdr.cdc.gov/interactionprofiles/ip04.html">http://www.atsdr.cdc.gov/interactionprofiles/ip04.html</a></li> <li>• Medical management guidelines (MMGs) for arsenic trioxide <a href="http://www.atsdr.cdc.gov/MHMI/mmg168.html">http://www.atsdr.cdc.gov/MHMI/mmg168.html</a></li> <li>• Medical management guidelines (MMGs) for Arsine <a href="http://www.atsdr.cdc.gov/MHMI/mmg169.html">http://www.atsdr.cdc.gov/MHMI/mmg169.html</a></li> </ul>
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## ToxFAQs Chemical Agent Briefing Sheet (CABS): Arsenic

	<ul style="list-style-type: none"><li>• Public Health Statement (PHS): Arsenic <a href="http://www.atsdr.cdc.gov/toxprofiles/phs2.html">http://www.atsdr.cdc.gov/toxprofiles/phs2.html</a></li><li>• ToxFAQs™: Arsenic <a href="http://www.atsdr.cdc.gov/tfacts2.html">http://www.atsdr.cdc.gov/tfacts2.html</a></li><li>• Toxicological profile for arsenic <a href="http://www.atsdr.cdc.gov/toxprofiles/tp2.html">http://www.atsdr.cdc.gov/toxprofiles/tp2.html</a></li></ul>
<b>EPA</b>	<ul style="list-style-type: none"><li>• Arsenic in drinking water <a href="http://www.epa.gov/safewater/arsenic/">http://www.epa.gov/safewater/arsenic/</a></li></ul>
<b>MedlinePlus</b>	<ul style="list-style-type: none"><li>• Arsenic <a href="http://www.nlm.nih.gov/medlineplus/arsenic.html">http://www.nlm.nih.gov/medlineplus/arsenic.html</a></li></ul>
<b>OSHA</b>	<ul style="list-style-type: none"><li>• Safety and health topics: Arsenic <a href="http://www.osha.gov/SLTC/arsenic">http://www.osha.gov/SLTC/arsenic</a></li></ul>
<b>USGS</b>	<ul style="list-style-type: none"><li>• Arsenic in ground-water resources of the United States <a href="http://water.usgs.gov/nawqa/trace/pubs/fs-063-00/">http://water.usgs.gov/nawqa/trace/pubs/fs-063-00/</a></li></ul>

### **For more information, contact:**

*Agency for Toxic Substances and Disease Registry  
Division of Toxicology and Environmental Medicine  
600 Clifton Road NE, Mailstop F-32  
Atlanta, GA 30333 Phone: 1-800-CDC-INFO (800-232-4636) TTY 888-232-6348*

*FAX: (770)-488-4178  
Email: [CDCINFO@cdc.gov](mailto:CDCINFO@cdc.gov)*