



Arsenic inorganic

Updated: November 2018

CAS number: 7440-38-2

Arsenic has chemical and physical properties intermediate between a metal and a nonmetal, and is often referred to as a metalloid or semi-metal [IARC].

In nature, arsenic occurs primarily in its sulfide form in complex minerals containing silver, lead, copper, nickel, antimony, cobalt, and iron. Arsenic is present in more than 200 mineral species, the most common of which is arsenopyrite [IARC].

Arsenic can exist in four oxidation states: -3, 0, +3 and +5. Elemental arsenic is not soluble in water. In water, arsenic is mostly found in inorganic forms as oxyanions of trivalent arsenite (AsIII) or pentavalent arsenate (AsV). Under oxidizing conditions, arsenate is dominant whereas, under reducing conditions, it is more likely to be present as arsenite [The Danish Environmental Protection Agency].

Inorganic arsenic generally refers to arsenic compounds with no carbon atoms.

From a biological and toxicological perspective, there are three major groups of arsenic compounds:

- inorganic arsenic compounds,
- organic arsenic compounds,
- arsine gas [IARC].

Arsenic is a naturally occurring element that is found in combination with either inorganic or organic substances to form many different compounds. Inorganic arsenic compounds are found in soils, sediments, and groundwater. These compounds occur either naturally or as a result of mining, ore smelting, and industrial use of arsenic [CDC].

Arsenic is a natural component of the earth's crust and is widely distributed throughout the environment in the air, water and land. It is highly toxic in its inorganic form [WHO].

Arsenic is emitted to the atmosphere from both natural and anthropogenic sources. Approximately one-third of the global atmospheric flux of arsenic is estimated to be from natural sources (7900 tonnes per year). Volcanic activity is the most important natural contributor, followed by low-temperature volatilization, exudates from vegetation, and windblown dusts. Anthropogenic sources are estimated to account for nearly 24000

tonnes of arsenic emitted to the global atmosphere per year. These emissions arise from the mining and smelting of base metals, fuel combustion (e.g. waste and low-grade browncoal), and the use of arsenic-based pesticides [IARC].

Arsenic is present in the air of suburban, urban, and industrial areas mainly as inorganic particulate (a variable mixture of AsIII and AsV, with the pentavalent form predominating) [IARC].

Usage and exposure

People are exposed to elevated levels of inorganic arsenic through drinking contaminated water, using contaminated water in food preparation and irrigation of food crops, industrial processes, eating contaminated food and smoking tobacco [WHO].

Inorganic arsenic is the predominant form found in meats, poultry, dairy products and cereal. It is estimated that approximately 25% of daily dietary arsenic intake is from inorganic sources [IARC].

In the past, inorganic forms of arsenic were used in pesticides and paint pigment. They were also used as wood preservatives and as a treatment for a variety of ailments. Today, usage of arsenic-containing pesticides and wood preservatives is restricted [CDC].

The primary route of arsenic exposure for the general population is via the ingestion of contaminated food or water. The daily intake of total arsenic from food and beverages is generally in the range of 20–300 µg/day. Inhalation of arsenic from ambient air is generally a minor exposure route for the general population [IARC].

People are most likely to be exposed to inorganic arsenic through drinking water and to a lesser extent through various foods. Water sources in some parts of the United States have higher naturally occurring levels of inorganic arsenic than other areas. Other sources of inorganic arsenic exposure include contact with contaminated soil or with wood preserved with arsenic [CDC].

Arsenic and arsenic compounds have been produced and used commercially for centuries. Current and historical uses of arsenic include pharmaceuticals, wood preservatives, agricultural chemicals, and applications in the mining, metallurgical, glass-making, and semiconductor industries. Arsenic was used in some medicinal applications until the 1970s [IARC].

Inorganic arsenic was used in the treatment of leukemia, psoriasis, and chronic bronchial asthma [IARC].

Inhalation of arsenic-containing particulates is the primary route of occupational exposure, but ingestion and dermal exposure may be significant in particular situations (e.g. during preparation of timber treated with chromated copper arsenate). Historically, the greatest occupational exposure to arsenic occurred in the smelting of non-ferrous metal, in which arseniferous ores are commonly used. Other industries or industrial activities where workers are or were exposed to arsenic include: coal-fired power plants, battery assembly, preparation of or work with pressure-treated wood, glass-manufacturing, and the electronics industry [IARC].

Arsenic is obtained as a by-product of the smelting of copper, lead, cobalt, and gold ores. Arsenic trioxide is volatilized during smelting and accumulates in the flue dust. Elemental arsenic can be prepared by the reduction of arsenic trioxide with charcoal [The Danish Environmental Protection Agency].

Arsenic is used industrially as an alloying agent, as well as in the processing of glass, pigments, textiles, paper, metal adhesives, wood preservatives and ammunition. Arsenic is also used in the hide tanning process and, to a limited extent, in pesticides, feed additives and pharmaceuticals [WHO].

Arsenic and arsenic compounds are used for a variety of other industrial purposes. Elemental arsenic is used in the manufacture of alloys, particularly with lead (e.g. in lead acid batteries) and copper. Gallium arsenide and arsine are widely used in the semiconductor and electronics industries. Because of its high electron mobility, as well as light-emitting, electromagnetic and photovoltaic properties, gallium arsenide is used in high-speed semiconductor devices, high power microwave and millimetre-wave devices, and opto-electronic devices, including fibreoptic sources and detectors (IARC, 2006). Arsine is used as a doping agent to manufacture crystals for computer chips and fibre-optic sources and detectors [IARC].

The lead components of lead-acid battery may contain arsenic, which release during the process of battery recycling [WHO 2017].

Today the most important industrial uses of arsenic are in the manufacture of GaAs and InAs semi-conductors, as a component of alloys and as a clarification and decolorising agent in the glass industry and in arsenic-containing paint pigments. It no longer plays any role in either the pharmaceutical industry or in plant protection agents [Arsenic species].

The chief sources of occupational exposure are the extraction of arsenic and its accompanying metals from ores containing arsenic, the use of raw materials containing arsenic in the semi-conductor and glass industries and the use of arsenic-containing

pigments in paints. In addition, arsenic and its compounds are introduced into nature as a result of the smelting of arsenic ores and the combustion of fossil fuels [Arsenic species].

Routs of exposure:

Inhalation, ingestion, skin absorption.

Inhalation of arsenic-containing particulates is the primary route of occupational exposure, but ingestion and dermal exposure may be significant in particular situations (e.g. during preparation of timber treated with chromated copper arsenate). Historically, the greatest occupational exposure to arsenic occurred in the smelting of non-ferrous metal, in which arseniferous ores are commonly used. Other industries or industrial activities where workers are or were exposed to arsenic include: coal-fired power plants, battery assembly, preparation of or work with pressure-treated wood, glass-manufacturing, and the electronics industry [IARC].

Target organs:

Gastrointestinal system, pulmonary system, haematoloic system, central and peripheral nervous system, liver, kidney.

Metabolism:

In the human body, inorganic arsenic compounds are converted to AsIII and AsV. AsV is rapidly converted to AsIII. AsIII species are more toxic and bioactive than are AsV species, both because of the greater chemical reactivity of AsIII, and because AsIII enters cells more easily [IARC].

Arsine generation atomic absorption spectrometry (AAS) is the method of choice for biological monitoring of exposure to inorganic arsenic. The absorbed dose of arsenic can be identified and quantified in hair, nail, blood or urine samples. Because arsenic accumulates in keratin-rich tissue, total arsenic levels in hair, fingernails or toenails are used as indicators of past exposures. In contrast, because of its rapid clearing and metabolism, blood arsenic, urine arsenic, and urine arsenic metabolites (inorganic arsenic, monomethylarsonic acid [MMAV] and dimethylarsinic acid [DMAV]) are typically used as indicators of recent exposure. In nonoccupationally exposed subjects, the sum of the concentration of the three metabolites in urine is usually less than 10 µg/g of creatinine [IARC].

The concentration of metabolites of inorganic arsenic in urine generally ranges from 5–20 µg/L, but may exceed 1000 µg/L (WHO, 2001). Time weighted average (TWA)

occupational exposure to airborne arsenic trioxide is significantly correlated with the inorganic arsenic metabolites in urine collected immediately after a shift or just before the next shift [IARC].

Health hazards

Unusually large doses of inorganic arsenic can cause symptoms ranging from nausea, vomiting, and diarrhea to dehydration and shock [CDC].

Central nervous system findings are highly variable, and range from none to seizures and encephalopathy. If the patient survives the initial phase, a second phase within 1 day to 1 week may feature cardiac arrhythmias, congestive cardiomyopathy, and non-cardiogenic pulmonary edema. A third phase that emerges 1-4 weeks after exposure may include anemia and leukopenia, and sensorimotor peripheral neuropathy [LaDou J].

Long-term exposure to high levels of inorganic arsenic in drinking water has been associated with skin disorders and increased risks for diabetes, high blood pressure, and several types of cancer. Inorganic arsenic and arsenic compounds are considered to be cancer-causing chemicals [CDC].

Chronic intake of subtoxic amounts of inorganic arsenic leads to brownish pigmentation of the skin, disturbance in the growth of the nails, and changes in the blood count in the form of anaemia [Arsenic species].

Long-term exposure to inorganic arsenic, mainly through drinking-water and food, can lead to chronic arsenic poisoning. Skin lesions and skin cancer are the most characteristic effects [WHO].

The Working Group reviewed a large body of evidence that covers ecological studies, case– control studies and cohort studies in a variety of settings and populations exposed either by ingestion (primarily to AsIII and AsV in drinking water) or inhalation (with exposure to a mixture of inorganic arsenic compounds). The observed associations between exposure to arsenic in drinking-water and lung cancer, and between exposure to arsenic in air and lung cancer, cannot be attributed to chance or bias. The evidence is compelling for both the inhalation and ingestion routes of exposure. There is evidence of dose–response relationships within exposed populations with both types of exposure. The observed association between exposure to arsenic in drinking-water and bladder cancer cannot be attributed to chance or bias. There is evidence of dose–response relationships within exposed populations. The observed association between exposure to arsenic in drinking-water and skin cancer cannot be attributed to chance or bias. There is evidence of dose–response relationships within exposed populations. The evidence is primarily for squamous cell carcinoma of the skin. The evidence for an association

between liver cancer and long-term exposure to arsenic in drinking-water relies on mortality data. Although the data strongly suggest a causal association with some evidence of a dose–response relationship, the Working Group could not rule out possible chance or bias. Although the evidence on prostate cancer suggests the possibility of a causal association, the Working Group could not rule out the possibility of chance or bias [IARC].

There is sufficient evidence in humans for the carcinogenicity of mixed exposure to inorganic arsenic compounds, including arsenic trioxide, arsenite, and arsenate. Inorganic arsenic compounds, including arsenic trioxide, arsenite, and arsenate, cause cancer of the lung, urinary bladder, and skin. Also, a positive association has been observed between exposure to arsenic and inorganic arsenic compounds and cancer of the kidney, liver, and prostate. Arsenic and inorganic arsenic compounds are carcinogenic to humans (Group 1) [IARC].

The Working Group made the overall evaluation on "arsenic and inorganic arsenic compounds" rather than on some individual arsenic compounds, based on the combined results of epidemiological studies, carcinogenicity studies in experimental animals, and data on the chemical characteristics, metabolism, and modes of action of carcinogenicity. Elemental arsenic and inorganic arsenic species share the same metabolic pathway: arsenate→arsenite→methylarsonate→dimethylarsenite. Thus, independent of the mechanisms of the carcinogenic action, and independent of which of the metabolites is the actual ultimate carcinogen, different inorganic arsenic species should be considered as carcinogenic [IARC].

References:

- Arsenic species (As(III), As(V), monomethylarsonic acid, dimethylarsinic acid). <https://onlinelibrary.wiley.com/doi/pdf/10.1002/3527600418.bi744038e0007>
- CDC. Arsenic. www.cdc.gov/biomonitoring/pdf/Arsenic_FactSheet.pdf
- IARC. Vol. 100C. 2012 pp: 41-94
<https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100C.pdf>
- LaDou J.: Current Occupational and Environmental Medicine, 5th ed., McGraw Hill Education, 2014. Pp 464-466
- The Danish Environmental Protection Agency. Arsenic, inorganic and soluble salts. <http://www2.mst.dk/Udgiv/publications/2014/01/978-87-93026-86-5.pdf>
- WHO. Arsenic. <http://www.who.int/news-room/fact-sheets/detail/arsenic>.
- WHO 2017. Recycling Used Lead-Acid Batteries: Health Considerations. <http://apps.who.int/iris/bitstream/handle/10665/259447/9789241512855-eng.pdf;jsessionid=E2B2711FD3BF4C6009D83F401D4BACFB?sequence=1>