Arsenic Testing at the Nebraska Public Health Laboratory

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Arsenic (As, mw 75) is a highly poisonous metallic element that is named from the Greek word arsenikon. Arsenic containing minerals have been known for centuries. Arsenikon is synonymous with orpiment which is an orange to yellow arsenic sulfide mineral (As_2S_3 or arsenic trisulfide). Arsenic sulfide (As_4S_4) which is also known as realgar (from the Arabic word rahjalghar meaning "powder of the mine") (1), was described by Aristotle in the 4th Century BC.

The Chemical Terrorism Preparedness Laboratory of the NPHL recently received the methodology from the Centers for Disease Control and Prevention (CDC) to test arsenic levels in urine. Arsenic is measured using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) instrumentation coupled with a Dynamic Reaction Cell (DRC) instrument. In addition to the ICP-MS, DRC is required to remove potential interferences that have the same molecular weight as arsenic. The methodology involves passing acidified urine through a nebulizer and spray chamber where the urine is ionized using high temperature (6000-8000°K) argon gas (hotter than the temperature of the sun). The ions, along with the argon gas, enter the mass spectrometer and pass through the DRC where the arsenic is separated from the interferences and enters the mass spectrometer where it is detected (based on mass to charge ratio) and quantitated.

Arsenic Levels in Nebraska

Arsenic and arsenic-containing compounds are found naturally in the environment with the main cause of arsenic poisoning from the ingestion of contaminated drinking water. In 2004, the U.S. Environmental Protection Agency (EPA) lowered the maximum contaminant level (MCL) in water from 50 parts per billion (ppb) to 10 ppb and required water systems to comply with this standard by January 23, 2006 (2). The EPA estimated that approximately 4,000 Public Water Systems (PWS) of the 74,000 PWS in the United States had to make changes to comply with this new regulation (2). According to the Nebraska Health and Human Services System there are currently 81 PWS in Nebraska that have arsenic concentrations above 10 ppb. These water systems serve nearly 100,000 people and are mostly found in the Panhandle and the western Sandhills regions of the state (3).

Arsenic Usage

Arsenic has several uses in agriculture, industry, and medicine. Historically, arsenic was used in cosmetics and as a pigment in paint and during the Victorian era was used as a cure-all medicine to treat everything from skin warts to fever and diabetes. Arsenic is now used in the manufacture of fungicides, insecticides, pesticides, and herbicides and in the semiconductor and transistors industry. In medicine, arsenic is used in several drugs. For example, arsenic trioxide (As_2O_3) is used to treat acute promyelocytic leukemia.

Arsenic as a Murder Weapon

Throughout history, arsenic has attained notoriety as a method for committing murder. Since the symptoms of arsenic poisoning can be confused with those of many other illnesses, it was difficult to detect arsenic after death which provided a practical way of murdering someone without getting caught. It was not until the development of a chemical test to detect for arsenic called the Marsh Test, that arsenic was proven to be used as a poison. Another less sensitive test was subsequently identified that could be used to detect arsenic, called the Reinsch test (1). Arsenic was such a common method for murder among the ruling class that it became known as the "Poison of Kings" and the "King of Poisons", and became referred to as the "Inheritance Powder". Several arsenic compounds are tasteless and colorless and have the appearance of white sugar which makes them undetectable by the victim(4). Napoleon Bonaparte is believed to have died of arsenic poisoning (1). Today, arsenic-containing compounds are considered a potential means for chemical terrorism. As a chemical warfare agent, dichloro(2-chlorovinyl)arsine (Lewisite) was first produced in 1918 to be used in World War I, however, the war ended prior to its use.

Arsenic and Health Effects

Long-term exposure to arsenic has been linked to cancer of the bladder, lungs, skin, kidneys, nasal passages, liver and prostate (5). Additionally, other health effects that have been documented include skin lesions, swollen nodes, cardiovascular disease, certain neurological disorders, diabetes, hearing loss, and hematological disorders (anemia and leucopenia) (5). Arsenic exerts its toxicity by inactivating up to 200 enzymes, most of them involved in the cellular energy pathways and in DNA replication and repair hence causing DNA damage (4).

Arsenic exposure today occurs mainly from drinking contaminated water, which is why the EPA

has tightened regulations on arsenic levels in water. Other exposure routes include inhalation, and absorption through the skin. Arsenic may be present in foods such as fish and algae in the relatively non-toxic organic form. Exposures to these organic compounds increases the arsenic levels in the blood following ingestion but are excreted rapidly through the urine. Arsenic, when present at high levels and unable to be excreted, tends to accumulate in various organs of the body and in the keratin-rich tissues, such as the nails, hair, and skin where it binds the thiol or sulfhydryl groups in tissue proteins (4).

Arsenic has had a continuing impact on human history over the ages. One reference to its effect survives in dermatology and pathology as actinic keratosis, an eruption of the skin originally due to arsenic poisoning and now used to describe skin damage to the sun. The ability to measure arsenic in urine is an important component of the chemical terrorism preparedness program at the NPHL. For more information about arsenic and testing for arsenic, please contact Dana El-Hajjar at 402-559-9421 or delhajja@unmc.edu.

References

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