Dynamic Adsorbents

Arsenic - Impact of Changes in EPA Enforced Environmental Legislation

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Overview

There is no known benefit to human health from arsenic. The prevalence of preventable chronic disease and death has led to reducing the acceptable public water level of arsenic from 50 to 10 parts per billion. The ideal goal would be having a zero level of tolerance, which is achievable using new technologies for environmental remediation. Funds from the 2009 stimulus package are now being directed to such environmental cleanup. Health cost savings of at least $200 annually are achievable by reducing the incidence of cancer by such environmental cleanup. Furthermore, the mechanism of action for arsenic causing disease has been elucidated.

The Metal and its Distribution

Arsenic occurs naturally in the earth's crust and possesses both metallic and non metallic properties. Arsenic is usually found combined with elements such as oxygen, chlorine and sulfur. Inorganic arsenic compounds tend to be more toxic than organic compounds. Inorganic arsenic is usually found as a solid at ambient temperatures. Certain geological formations contain high levels of arsenic that can easily leach into groundwater and reach wells and other public water supplies. Higher levels of arsenic tend to be found more in ground water sources than in surface water sources of drinking water, such as lakes and rivers. Arsenic in water is tasteless, odorless and colorless. In the United States, the western third of the country has more public water systems and wells with high arsenic levels. Chronic arsenic poisoning from water exposure is a major public health care issue in Taiwan, South America, and the Indian subcontinent. In Bangladesh one of every ten adult deaths is caused by arsenic related cancers. A total of 100 million people in the world are exposed to high levels of arsenic in their water supply.

90% of the arsenic used for industrial purposes is dedicated to the manufacture of wood preservatives, while the rest of industrial arsenic is used as pesticides for agriculture, and in the production of glass, non ferrous alloys, drugs, soaps and semiconductors. Man made arsenic releases are a by-product from copper, zinc and lead smelters. In North America, China and Western Europe the man made release of arsenic comes primarily from the burning of coal.

Acceptable Levels in the Environment

The Environmental Protection Agency established a higher drinking water standard for arsenic at 10 parts per billion which went into effect in January, 2006. This standard is equivalent to the standards adopted by the World Health Organization and the European Union. This standard was promulgated in response to a congressional mandate and a comprehensive

study by the National Academy of Sciences. Arsenic standards are based on risk assessment models from high exposure populations. The National Academy of Sciences determined in 1999 that chronic exposure to arsenic via the ingestion of drinking water led to an increased risk in the incidence of the following malignancies – lung, bladder, skin, liver and kidney cancers. . The International Agency for Research on Cancer (IARC) has classified arsenic as a Group I human carcinogenic substance.

Excess Injury Due to Arsenic Exposure

The previous standard had been 50 parts per billion, which over a 70 year lifetime gave an individual a 1 in 100 chance of developing a solid tumor malignancy based just upon drinking water! This is roughly equivalent to the risk of death over a lifetime from motor trauma. The EPA has estimated that the reduction in the acceptable level of arsenic in the water supply will lead to a statistically significant reduction in the incidence of solid tumors – for example, it is estimated that there will be a reduction in the incidence of lung cancer by 19-25 cases annually, and in the incidence of bladder cancer by 19-31 cases annually.

Additionally, exposure to arsenic increases the risk for hypertension, diabetes and cardiovascular disease. A spectrum of disease reduction is anticipated with compliance to the new water standards for arsenic. The annual savings in health care costs will exceed $200 million.

Many parts of the United States have high underground water concentrations of arsenic. In New Hampshire, where 40% of the population derives their water supply from private wells, as much as 8% of the population is exposed to arsenic levels of between 10 and 50 ppb, with many wells having arsenic concentrations of between 100 and 800 ppb.

Mechanisms of why arsenic is so dangerous to human health are being developed by medical researchers. It has been theorized that arsenic alters the function of the glucocorticoid receptor as a transcription factor. Glucocorticoids induce cellular and physiological effects mediated predominantly through an interaction with the steroid receptor hormone GR. Upon steroid binding GR is altered which unmasks a DNA binding domain, which leads to a translocation of the ligand bound GR to the nucleus in a form that can interact with DNA. In so doing GR can then led to either positive or negative effects on transcription of specific glucocorticoid responsive genes. It is postulated that GR mediates suppression of tumor promotion in skin and lung by suppressing cell growth and inducing differentiation. Down regulation of GR or loss of function induced by arsenic may be permissive for tumor growth.

Furthermore it has been proposed by researchers at the Dartmouth Medical School that arsenic may be able to act synergistically with other toxic and carcinogenic agents to increase disease risk. There is a significant increase in the risk of malignancies when there is an increased exposure to both arsenic and cigarette smoking.

For these reasons, the goal is to establish a zero tolerance limit for arsenic. It is not a compound which has been shown to be of any value to mankind. As it is endemic in our soil and in our water it is essential that a cost effective method be shown to remove arsenic and reduce the risks to health. As with most environmental challenges the impact of arsenic is most serious in infants and the aged.

In surface and groundwater arsenic occurs primarily as arsenite (+++) (H3As03) or arsenate (+++++) (H2As04-). Arsenite is significantly more toxic than arsenate. The presence of oxygen oxidizes arsenite to five valent arsenate, and therefore the oxidation state is an important design consideration in the treatment of water. Both these species of arsenic are present in water as dissolved anions. Current separation techniques require that in order to remove arsenite it is necessary to pre-oxidize arsenite to the arsenate species. In order to do so many water purification systems have a dedicated oxidation column in order to supplement the oxidation capacity available in adsorption media. This is a costly and bulky solution, but is essential in order to be able to effectively remove both forms of inorganic arsenic.

The US Environmental Protection Agency guidelines revised the current Maximum Contaminant Level for arsenic to 10 parts per billion (10 ug/L) and sets a Maximum Contaminant Level Goal of zero for arsenic in drinking water. This requirement is in enforcement for both community water systems and non transient non community water systems. A community water system is defined as a public water system that serves at least 15 locations or 25 residents regularly year round. Compliance with this standard is voluntary for private well owners that do not fall within the definition of a community.

In most instances health authorities require arsenic to be tested as part of the suite of tests taken before a real estate transaction can be completed. If arsenic levels are above 10 ug/L the seller of the home may be required to drill a new well or provide a system or device to reduce the arsenic levels to below the Maximum Contaminant Level (MCL).

Arsenic Remediation Solutions

There are several commercial solutions available in the marketplace offering the means to clean up arsenic to below the drinking water standard of 10 ug/liter. The spectrum of solutions offered include such technologies as reverse osmosis, ion exchange, coagulation microfiltration and activated alumina. Adsorption technologies have gained the most favor during the past 5 years due to ease of use, cost, and efficiency. Currently available treatment technologies include the following solutions:

- Activated Alumina
- Activated Carbon (organic complexes)
- Anion Exchange
- Coagulation Filtration
- Distillation
- Iron Alumina Media
- Iron Oxide Media
- Granulated Ferric Hydoxide
- Granulated Ferric Oxide
- Reverse Osmosis

As noted above there are clearly multiple technologies and the end user must decide upon factors such as cost, availability, ease of use and convenience and removal of waste in determining what is best for their particular needs.

When using an adsorption technology, which is currently the preferred method for arsenic removal, it is best to use a material which is non leachable. The arsenic should remain

chemically bound to the adsorbent media such that the material is able to pass the EPA criteria for Toxic Characteristic Leaching Procedure Levels (TCLP). This will allow the arsenic bound adsorbent material to be removed in a cost effective, non hazardous fashion. Ideally, there should be no sludge for disposal and the adsorbent selected should be effective over a wide range of temperature conditions and pH, and be resistant to both microbial growth and oxidation.

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