
Arsenic poisoning: A world – wide threat

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Abstract

Arsenic has been used since 3000 BC. Arsenic is highly toxic in its inorganic form. Contaminated water used for drinking, food preparation and irrigation of food crops poses the greatest threat to public health from arsenic. Long-term exposure to arsenic from drinking-water and food can cause cancer and skin lesions. A short review is presented here to put forward the side-effects of arsenic contaminations.

Keywords:

Arsenic pollution;
Toxic substance.

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1. Introduction

Arsenic occurs mainly as sulphides and relative abundance in earth's crust is $5 \times 10^{-4}\%$. Arsenic is amphoteric in nature and exhibit intermediate properties and hence it is often termed as metalloids. Arsenic has been used since 3000 BC. In the United Kingdom, for example, it was used to extract iron from iron ore. Arsenic is highly toxic in its inorganic form. Contaminated water used for drinking, food preparation and irrigation of food crops poses the greatest threat to public health from arsenic. Long-term exposure to arsenic from drinking-water and food can cause cancer and skin lesions. Arsenic contamination of groundwater is a form of groundwater pollution which is often due to naturally occurring high concentrations of arsenic in deeper levels of groundwater. Arsenic contamination in groundwater in the Ganga- Brahmaputra fluvial plains in India and. Padma-Meghna fluvial plains in Bangladesh and its consequences to the human health have been reported as one of the world's biggest natural groundwater calamities to the mankind. In India, seven states namely- West Bengal, Assam, Bihar, Tripura, UP, Jharkhand, and Uttarakhand. It has long been known that arsenic is acutely toxic. Anyone who drinks arsenic in water at 60 parts per million (ppm) will soon die. There are several toxicological summary references for acute effects available on the web such as SCORECARD, ASTDR, USEPA and LSUMC.

2. Research Method

Chronic effects of prolonged low-level exposure have recently showed up. Among various summaries we link to an information site run by ASTDR. Skin pigmentation, keratoses and skin cancers were found by Tseng in Taiwan in 1966 among people who drank from arsenic contaminated wells (but no effect was seen below about 150 parts per billion (ppb), which might therefore be a biological threshold) and a very high incidence of lung, bladder and other cancers was found in Taiwan by Dr. Chien-Jen Chen in 1986 and by Dr Allan Smith and collaborators in Chile in 1993. These convinced WHO to recommend lowering the regulatory level from 50 ppb to 10 ppb for arsenic in water. It appears that there are no data on humans to contest the idea that prolonged exposure to low doses is dangerous. Although arsenic was used medicinally in "Fowler's Solution" (1% arsenite), prolonged use had led to these chronic skin effects. This was observed as early as 1888 by Hutchinson. A follow up of a number of English patients treated with Fowler's Solution has

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been reported by Dr Susan Evans in published literature, in a report at the February 1998 conference in Dhaka and in a presidential address by Susan Evans to the Liverpool Medical Institute, which is available for download in PDF format. This shows that the use of "Fowler's solution" (which is primarily medicinal arsenic) in the UK is probably responsible for 5 bladder cancer cases among the patients among whom only 1.6 were expected from natural causes. The arsenic dose was equivalent to an average lifetime dose that would come from drinking water with about 25 ppb of arsenic therein.

After several years of low level arsenic exposure, various skin lesions appear. These are manifested by hyperpigmentation (dark spots), hypopigmentation (white spots) and keratoses of the hands and feet. After a dozen or so years skin cancers are expected. Twenty or thirty years after exposure to 500 ppb of arsenic, internal cancers (lung, kidney, liver and bladder) appear among 10% of all exposed. Moreover, the dose-response relationship for these internal cancers is consistent with being linear with no threshold.

Arsenic contamination has become a problem in many parts of the world. At first as a result of leaching from mine tailings in Australia, Canada, Japan, Mexico, Thailand, United Kingdom, and the United States, but now also from the arsenic in natural aquifers now or recently used for water supply in Argentina, Bangladesh, Cambodia, Chile, China, Ghana, Hungary, Inner Mongolia, Mexico, Nepal, New Zealand, Philippines, Taiwan, the United States and Vietnam. Arsenic was also widely used as a pesticide. 20,000 tons a year was imported into the USA, and perhaps double that amount was used, to spray on crops in the USA alone. No attention was paid to the ultimate fate of the chemical, and in consequence arsenic now appears in foodstuffs. (Papers describing data in some of these countries are listed by country in the list of useful references). It is important to distinguish the problems in Bangladesh, West Bengal and, to a lesser extent, Inner Mongolia, Chile, Nepal and Vietnam, from the problems that have been found so far in the rest of the world. These situations have in common that they are an alluvial plain where arsenic has been brought down from the surrounding hills for millennia. It seems that no one has looked carefully at similar geological situations such as the Mekong delta or the Irrawaddy delta. In most of the world exposures above 50 parts per billion (50 ppb) are rare, and once observed, can easily be avoided. But the sheer scale of the problems in Bangladesh dwarfs the imagination. The catastrophe is much worse than the well-known catastrophe of the Chernobyl nuclear power plant accident, the Bhopal isothiocyanate leak or the Kuwait oil fires. For 90% of the Bangladeshi communities, pure water is still a long time away.

In six districts of West Bengal arsenic has been found in ground water above the maximum permissible limit recommended by the WHO of 0.05 mg l^{-1} . This water is used by the villagers for drinking, cooking and other household purposes. These six districts have an area of 34 000 km^2 and hold a population of 30 million. Over the last five years we have surveyed only a few small areas of these six affected districts and our survey revealed that, at present, at least 800 000 people from 312 villages in 37 blocks are drinking contaminated water and more than 175 000 people are showing arsenical skin lesions that are the late stages of manifestation of arsenic toxicity. Most of the three stages of arsenic-related clinical manifestations are observed amongst the affected people. The common symptoms are conjunctivitis, melanosis, depigmentation, keratosis and hyperkeratosis; cases of gangrene and malignant neoplasms are also observed. The source of arsenic is geological. We have analysed thousands of arsenic contaminated water samples. Most of the water samples contain a mixture of arsenite and arsenate and in none of them could we detect methylarsonic or dimethylarsinic acid. We have also analysed a large number of urine, hair and nail samples, several skin-scales and some liver tissues (biopsy samples) of the people drinking the arsenic contaminated water and showing arsenical skin lesions. Flow injection hydride generation atomic absorption spectrometry (FI-HGAAS) was used for the analysis of hair, nails, urine and skin-scale after decomposition by various techniques. The liver tissues were analysed by Zeeman corrected-ETAAS using a few milligrams of the biopsy samples.

Arsenic is plentiful in the ground. Yet it does not always appear in the water supply. Scholars at the Cambridge University Department of Geography have identified the following mechanisms for arsenic entering the water which vary between locations, Alkali-desorption, Geothermal, Reductive dissolution and Sulphide oxidation. Although the worst arsenic catastrophe is in Bangladesh, where 35 million people are exposed to levels above the US EPA standard, the amount of arsenic in the soil is less than in many other areas, including areas such as Massachussets, USA, where it does not, nonetheless, appear in unsafe quantities in ground water. In most of these areas, such as the delta of the Ganges and Irrawaddy, and the bend of the Yellow river, arsenic has come down from the mountains over millenia, attached itself to iron, forming iron pyrites, and been deposited. Professor McArthur of UC London argues: "It becomes increasingly clear that severe arsenic pollution of ground water in most alluvial aquifers worldwide is driven by the microbially-mediated metabolism of organic matter, with FeOOH acting as the source of oxygen: the oxide is reduced during the process and its sorbed arsenic is released to ground water. Despite the widespread acceptance of this mechanism, much about it remains obscure." One issue is whether the reduction takes place at the surface before the water filters down to the aquifer in the monsoon.

An older idea was that water was being drained from the aquifer, allowing oxidation. A recent paper describing arsenic contamination in Perth, Australia - shows that there is one location, in Perth where pyrite

oxidation clearly WAS the source of the As (although there is evidence that anaerobic release from Fe oxyhydroxides is also taking place deeper in the aquifer). But the ideas that pyrite oxidation is the problem in Bangladesh whether caused by recent rapid pumping that allowed for oxidation and release of arsenic, or by the man-made change in river flow, such as the barrage across the Ganges are now considered to be untenable.

In the Americas, from Alaska in the north, through Crater Lake in Oregon, Mono Lake and Searles Lake in California, volcanic lakes in Nicaragua and Costa Rica, and on to the Andes, lie a chain of volcanic activity that brings arsenic to the surface. This mechanism of sulfate reduction in the arsenic-rich soda lakes (Mono Lake and Searles Lake) of is being studied in detail by Dr Oremland and his group at the US Geological Survey in Menlo Park. They attributed the mechanism to bacteria, but of course different bacteria from those responsible for the reduction of iron pyrites in South East Asia and Bangladesh. Presumably this is the same mechanism which is responsible for the arsenic pollution in the mountains of Argentine and Chile where so much epidemiological studies have been made.

For the past dozen years, Houston-based scientists Dr Prodyot and Krishna Day have been camping out in their native Kolkata, working on a mission to educate the people about the dangers lurking in their drinking water, more specifically, the presence of arsenic in the water tables of rural and semi-urban area of West Bengal and Bangladesh. "There are so many people with skin lesions that are the first visible symptoms caused by drinking water contaminated by arsenic," says Prodyot Day. Many more years of drinking such water can affect the lungs, pancreas, stomach, esophagus and lead to cancer of these organs, he said. Arsenic is a reactive metalloid (semi metal) that occurs mainly as minerals of iron, copper, lead, manganese, etc. Volcanic activity mainly accounts for occurrence of these minerals. Over the years they are broken down by weathering and carried along by streams and find them in higher concentration underground than on the surface. Water from such aquifers contains varying amounts of arsenic, sometimes in concentrations high enough to cause arsenic poisoning when ingested. The result is manifested within a few years as skin lesions, known as keratosis and melanosis. Then after some more years they get cancer of the skin, lung, kidney, bladder and liver (Figure 1). Other medical conditions caused by arsenicosis are stomach troubles, sleep disorder, cardiovascular disease, neurological problems, and diabetes mellitus. With present day knowledge of arsenicosis, no amount of arsenic in drinking water is considered safe.

A drinking water standard of 0.05 mg/L (equal to 50 parts per billion, or ppb) arsenic was originally established in the United States by the Public Health Service in 1942. The Environmental Protection Agency (EPA) studied the pros and cons of lowering the arsenic Maximum Contaminant Level (MCL) for years in the late 1980s and 1990s. No action was taken until January 2001, when the Clinton administration in its final weeks promulgated a new standard of 0.01 mg/L (10 ppb) to take effect January 2006 [1]. The Bush administration suspended the midnight regulation, but after some months of study, the new EPA administrator Christine Todd Whitman approved the new 10 ppb arsenic standard and its original effective date of January 2006 [2]. Many locations exceed this limit. Cases of groundwater-caused acute arsenic toxicity, such as those found in Bangladesh, are unknown in the United States where the concern has focused on the role of arsenic as a carcinogen. The problem of high arsenic concentrations has been subject to greater scrutiny since 2001, when the federal government promulgated a new lower standard for arsenic in drinking water.

Many public water supply systems across the United States obtained their water supply from groundwater that had met the old 50 ppb arsenic standard but exceeded the new 10 ppb MCL. These utilities searched for either an alternative supply or an inexpensive treatment method to remove the arsenic from their water. In Arizona, an estimated 35 percent of water-supply wells were put out of compliance by the new regulation; in California, the percentage was 38 percent [3].



Figure 1. Common symptoms of Arsenic poisoning (left: Keratosis; right: Arsenic lesions)

3. Results and Analysis

The proper arsenic MCL continues to be debated. Some have argued that the 10-ppb federal standard is still too high, while others have argued that 10 ppb is needlessly strict. Individual states are able to establish lower arsenic limits; New Jersey has done so, setting a maximum of 0.005 mg/L for arsenic in drinking water [4]. A study of private water wells in the Appalachian Mountains found that six percent of the wells had arsenic above the U.S. MCL of 0.010 mg/L [5]. A review of methods to remove arsenic from groundwater in Pakistan summarizes the most technically viable inexpensive methods [6]. A simpler and less expensive form of arsenic removal is known as the Sono arsenic filter, using three pitchers containing cast iron turnings and sand in the first pitcher and wood activated carbon and sand in the second [7]. Plastic buckets can also be used as filter containers [8]. It is claimed that thousands of these systems are in use and can last for years while avoiding the toxic waste disposal problem inherent to conventional arsenic removal plants. Although novel, this filter has not been certified by any sanitary standards such as NSF, ANSI, WQA and does not avoid toxic waste disposal similar to any other iron removal process.

In the United States small "under the sink" units have been used to remove arsenic from drinking water. This option is called "point of use" treatment. The most common types of domestic treatment use the technologies of adsorption (using media such as Bayoxide E33, GFH, or titanium dioxide) or reverse osmosis. Ion exchange and activated alumina have been considered but not commonly used. Chaff-based filters have been reported to reduce the arsenic content of water to 3 microgram/litre. This is especially important in areas where the potable water is provided by filtering the water extracted from the underground aquifer [9].

4. Conclusion

More advanced and sensitive techniques to detect minute levels of arsenic are to be devised. More awareness is required especially in the rural areas regarding the side-effects of arsenic contamination. This is how the threats of arsenic poisoning can be controlled.

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