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Exposure to Arsenic in Drinking Water-Public Health Debates and Concerns

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Abstract: Providing potable water to populations world-wide is an important agenda in the public health arena. In this regard, many nations have embraced well drilling resulting in a significant reduction in waterborn diarrhoeal diseases. Unfortunately, much of the earth's crust is saturated with arsenic which filters into the waters and may have health implications when used for drinking. The delayed health effects of exposure to arsenic and lack of local awareness of possible effects of arsenic make it mandatory for all wells and any source of underground water to be tested for the element. The literature shows that no one continent is spared from arsenic contaminations and poisoning. The disease burden and the consequent health care cost on individuals, families, communities and nations remain a debate and a policy issue. The review describes the public health problem of arsenic exposure with aspects on the source of exposure, risks of exposure, the problem with arsenic from drinking water, dietary exposure of arsenic, and challenges to surveillance.

Key words: Arsenic, exposure, drinking water and debates

INTRODUCTION

The impetus for this research was the conviction to create awareness in order to realize the problem of arsenic poisoning from ground water and the resulting health consequences in human populations as well as the health care cost for governments and families. To do this, we must understand the distribution of arsenic in the earth's surface, critically consider the sources of exposure and health impacts and to learn from them.

SCIENTIFIC BACKGROUND OF ARSENIC

Arsenic is a naturally occurring element, widely distributed in the earth's crust. It is present in food, soil, air, and water, and all human populations are exposed to it in one form or another (Abernathy *et al*., 1999; WHO, 2009). The adult human body is thought to contain approximately 20mg – distributed in all tissue with higher concentrations in the skin, hair and nails (Katze, 2001).

Food contains both organic and inorganic forms of arsenic, whereas drinking water contains primarily inorganic forms of arsenic. There has not been any established Recommended Daily Allowance (RDA) but an intake of 12 to 15 µg per day is reported to be appropriate for adults (Katze, 2001). There is lack of any toxicity reports from dietary sources. However, toxicity reports from ingestion of concentrated arsenic from water as well as industrial exposure have been extensively documented (Abernathy *et al*., 1999; Van Green *et al*., 2002; Gebel, 2000; Armienta *et al*., 1997).

SOURCES OF EXPOSURE

Since arsenic is found throughout the earth's crust in a variety of compounds coupled with its ubiquitous nature in the environment, human exposure to arsenic is inevitable. Therefore, exposure can occur through the inhalation of air, through the ingestion of food and water, and via dermal absorption. Generally, the degree of non-occupational exposure to arsenic varies greatly, and this is dependent on the local geochemistry as well as the level of anthropogenic activity. Given the above factors, it can be said that arsenic is a natural contaminant of ground water, as well as drinking water, which translates into a public health issue worldwide. As the world population increases, one of the most fundamental resources for human survival, clean water, is decreasing.

The world water resource is diminishing, and one in every five persons does not have access to clean drinking water (BBC News, 2009). The rising demand for sanitary water cannot be met by surface water supplies, and this has resulted in dependence on underground water resources in many parts of the world. In Ghana and most African countries, the use of underground water is on the rise as lakes and other surface waters dry up due to environmental degradation. The need to assess the water quality of the various sources of underground water cannot be overemphasized.

It must be mentioned, however, that the risk of exposure via the three major pathways mentioned above are dependent on the bioavailability of the element.

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Levels of arsenic in ambient air are generally low but higher levels (1000 ng/m^3) have been seen in the vicinity of non-ferrous metal smelters (WHO, 2009). In air, arsenic exists predominantly as particulate matter, and is usually present as a mixture of arsenate and arsenite. The organic species (arsenic in combination with C and H) is of negligible importance, except in areas of arsenic pesticide application or biotic activity (Beavington and Cawse, 1978; Davidson *et al.*, 1985).

It is also worth mentioning the detection of arsenic in rain water. This is also an important source of exposure, especially in polluted areas where the mean concentrations range from 0.013 to 0.5µg/L, while near a North Sea gas platform, mean concentrations up to 45 µg/L have been reported (Peirson *et al.*, 1974; Andrea, 1980; Scudlark and Church, 1988). Background concentrations of arsenic have been recorded in non-contaminated soil and soil overlying arsenic rich geological deposits. The relative bioavailability of these is very low, and based on rat model, bioavailability of arsenite and arsenate range from 1.0 to 9.9% and 0.3 to 3.0% respectively (WHO, 2002).

Arsenic is widely distributed in surface water. Measured values below 10 µg/dL are common (Smith *et al.*, 1987; Welch *et al.*, 1988). Nonetheless, the scientific literature shows areas having elevated ground water concentrations of arsenic, either naturally occurring or due to human activity, have been observed in major regions of the world. For example, in Iowa, Missouri and Ohio, arsenic of natural origin was found in ground waters at concentrations between 24 and 491 µg/L (Korte and Fernando, 1991; Matisoff *et al.*, 1982). Furthermore, in India, Bangladesh, Ghana and other parts of the world, arsenic contamination of ground water has been reported by Garelick *et al.*, 2008 and Smith *et al.*, 2002.

Risks of exposure: According to WHO (2009), the daily intake of total arsenic is from the consumption of food and beverages in the general population. Intake between 20 to 300 µg/day has been seen, and this wide range is a reflection of the composition of diets and sources of water used in the preparations of beverages. In addition to food, drinking water is a significant source of both total and inorganic arsenic. ATSDR (2002) documented that all other intakes of arsenic (inhalation and dermal) are usually small in comparison to the oral route.

The literature clearly outlines the health effects of exposure. Chronic arsenic poisoning, which occurs after long-term exposure through drinking water, is very different from acute poisoning. Immediate symptoms on an acute poisoning typically include vomiting, esophageal and abdominal pain, and bloody "rice-water" diarrhea (WHO, 2002). The symptoms and signs of arsenic toxicity differ between individual population groups and geographic regions.

Long-term exposures to arsenic via drinking water are known to cause cancer of the skin, lungs, urinary bladder and the kidney. Skin changes including pigmentation and thickening (hyperkeratosis) have also been recorded (Mandal and Suzuki, 2002; WHO, 2009). Increased risk of lung and bladder cancers and of arsenic-associated skin lesions has been associated with drinking water, in concentrations of as low as 0.05mg/L. It is important to mention here that absorption of arsenic through the skin is minimal, therefore, hand-washing, bathing and laundry, etc. with arsenic containing water does not pose a significant human health risk. Arsenic has been implicated in causing health problems such as hypertension, diabetes, and reproductive disorders and endocrine disruption (Mandal and Suzuki, 2002; Tseng, 2004; Navas-Acien *et al.*, 2008; WHO, 2009).

It is now evident that the major route of toxicity is the oral route - and drinking water is the main source. In Bangladesh, for example, surface water is heavily contaminated with infectious disease pathogens from sewage such that mortality from drinking such water was very high. This was an important public health concern. To combat this problem, the government and UNICEF in conjunction with other NGOs encouraged installation of tube wells that tap into the underground aquifers (The New York Times, 2002). Tappings into sterile subsurface water supplies seemed to be an excellent solution to the problem, and millions of wells were constructed in Bangladesh during the past twenty years. No sooner were the wells set up, was it realized that the ground water was heavily loaded with arsenic. Thus, in trying to solve a problem by providing "safe" drinking water, another one was being created. Therefore, Bangladesh is now facing a long-term epidemic of cancers and other fatal diseases because of the contamination of water supplies by naturally occurring arsenic (Smith *et al.*, 2000; WHO, 2002). WHO puts the whole situation in perspective by saying "Bangladesh is grappling with the largest mass poisoning of a population in history…the scale of the environmental disaster is greater than any seen before. It is beyond the accidents at Bhopal, India, in 1984 and Chernobyl, Ukraine, in 1986." The discovery of arsenic contamination of ground water in many countries, (China, Argentina, Chile, Taiwan, United Kingdom Finland, Italy, Thailand, United States, Ghana, South Africa, Zimbabwe, Bangladesh, Australia to mention a few), shows that arsenic toxicity is a global problem (no continent is spared) and needs to be addressed (Petrusevski *et al.*, 2007).

Arsenic toxicity is real, and health implications have been recorded across the globe. There is, however, more to do to address this issue, and the next section focuses on some of the controversies related to arsenic exposure

Problems with Arsenic and Drinking Water: During the last century, steps have been taken to develop the technology and social policy to address questions of access to potable water and means of improving water quality. To date, problems still exist, even in developed countries, including the United States, Western European nations, and Japan, not to mention developing countries where drinking water supplies contain arsenic, other chemicals, and bacteria, just to mention a few. In the United State for example, fertilizers and pesticides spread on farms and lawns filter through the ground into the water table or wash into streams and lakes, which supply some of the nation's drinking water (Tibbetts, 2000; Garelick *et al*., 2008).

In many poor villages around the world, people have to rely on the water that's easiest to reach – groundwater, rivers, and streams. Thus, the effects of the introduction of arsenic contaminated water from industrial effluent cannot be underestimated. In well-oxygenated surface waters, arsenic (V) is the most common species present but, under reducing conditions such as those found in groundwater, the predominant form is arsenic (III), which has increased solubility and high affinity for proteins, thereby making it more toxic. (Welch *et al*., 1998). Also, as pH rises, there is an increasing concentration of dissolved arsenic in water (WHO, 2002).

Another problem is the delayed health effects after exposure to arsenic (latency). This is of critical concern, and the Bangladesh example clearly gives an in-depth view into the problem globally. At the time that (groundwater) tube wells were encouraged (over twenty years ago), arsenic was not recognized as a problem in water supplies, and standard water testing procedures did not include a test for it. The problem of arsenic exposure came to light when doctors first saw cases of arsenic-induced skin lesions, in West Bengal, India in 1983.

Apart from the delayed health effects of exposure to arsenic, other major problems of global concern are; the lack of common definitions for arsenic toxicity and of awareness, as well as poor reporting in affected areas. These form the stumbling blocks in determining the extent of the problem of arsenic in drinking water.

To date, reliable data on exposure and health effects are scarce. In 1988, the British Geological Group surveyed sixty-one out of the sixty-four districts in Bangladesh with shallow tube wells and found that 46% of the samples had As levels greater than 0.01 mg/L and 27% were greater than 0.05 mg/L. The data estimated that people exposed to arsenic concentrations above 0.05 mg/L. was between 28 to 35 million and that of greater than 0.01 mg/L was 46 to 57 million (Smith *et al*., 2000). Cost of health care in the treatment and managing of arsenic toxicity, inability of affected persons to engage in productive activities and potential social isolation are important global consequences of economic and social behaviors associated with arsenic poisoning.

Debates Related to Exposures: It has been argued that nutrition plays an important role in the manifestation of arsenic exposure. In Taiwan, for instance, arsenic has been linked to the Blackfoot disease (BFD) (Tseng, 2002). The condition is characterized by an insidious onset of coldness and numbness in the feet, followed by ulceration, black discoloration and subsequently dry gangrene of the affected parts. The high prevalence of BFD in Taiwan has not been found elsewhere (Tseng, 2005). Other scientists, however, postulated that factors such as malnutrition or concurrent exposures to other environmental toxins play roles in the causal path of the disease (Smith *et al*., 2000 and Hsueh *et al*., 1997)

There have also been arguments about the biomarkers of arsenic exposure. The most commonly used markers to identify or quantify arsenic exposure are total arsenic in hair or nails, blood arsenic and total or speciated metabolites of arsenic in urine. Arsenic (III) is known to accumulate in keratin-rich tissue such as the skin, hair and nails, and that has been used as an index in the exposure assessment. Hair and nails are readily available, and as such, non-invasive sampling is an advantage. Nevertheless, there have been counter arguments that arsenic in skin, hair or nails could be from external contamination and do not give a true reflection of exposure. Further, arsenic levels in hair and nails can be influenced by arsenic -induced disease state, (Lin *et al*., 1998; Armienta *et al*., 1997). The use of toenails, rather than fingernails, has been recommended in some studies. This is because large amounts of samples can generally be obtained. Toenails also have the added advantages of slower growth and therefore reflect exposures in the more distant past as well as recent external contaminations (Karagas *et al*., 1996; Garland *et al*., 1993).

There have been problems regarding the best body substrate to use in determining arsenic levels. Studies have shown that blood arsenic does not correlate well with the arsenic content in the water, particularly at low levels. However, work by Valentine *et al* (1979) showed that water levels of arsenic correlate very well with total arsenic in urine. In common with the other biomarkers, arsenic levels in urine may result from exposures via inhalation, food, soil and water, which is an index of total absorbed dose. The use of total urinary excretion as a biomarker is now obsolete since it does not give a better index of exposures from inorganic sources such as drinking water, resulting in an under estimation of inorganic arsenic exposure. This is so because of the interference from dietary sources such as high intake of seafood. To eliminate this potential confounder, there is the need to collect data on dietary history or to ask the subjects to withhold the consumption of seafood at least two days prior to urine collection.

Challenges to Surveillance: The main aim of surveillance is to prevent exposure to arsenic in drinking water and also to control the levels of arsenic in water in order to provide safe drinking water. The two important issues influencing the prevention and control schemes are cost and government policies. Conditions under which exposure to arsenic in humans need to be more fully characterized, for example, how hair and nail arsenic levels compare with urine analysis. This may help provide data to define dose-response relationships to ascertain valid risk assessment.

As in the case of Bangladesh, there is the need to integrate continuing education and monitoring into existing health services whether governmental or non-governmental. The importance of compliance with treatment programmes as well as nutrition cannot be over-emphasized. Community field workers should make regular visits to areas most affected. These workers should be equipped with continuous education plan and field kits for urine testing. Without field kits, monitoring of arsenic levels become cumbersome and is often delayed since samples should be sent to reference laboratories. Although, there is the need for field kits, it is also important to note that field test-kits can detect high levels of arsenic but are usually unreliable at lower concentrations critical for human health.

Another factor challenging surveillance is the technical know- how. Accurate measurement of arsenic in drinking water at levels relevant to health requires laboratory analysis, using sophisticated and expensive technologies and facilities, as well as trained staff, which are not easily available or even affordable in many developing countries (Smith, 2002). Alternate methods within the socio-cultural and political framework of the population in the developing world are most appropriate. The precautionary principle and public health should be the major influences and guidelines along which the alternate risk managements are based.

CONCLUSION

Arsenic toxicity is a real threat to the world. The Bangladesh case is a wake-up call to the world to act now to provide appropriate technologies globally so as to provide safe drinking water for all. Furthermore, as arsenic is widely distributed and exposure routes vary, continuous monitoring of all sources coupled with health education is needed. It is also timely that regions where levels are low and and incident cases have not reached epidemiological concern should find it mandatory to curb the situation now. This is very true for developing countries who are already over burdened with both under- and over nutrition, for to be warned is to be armed. Taking the precautionary principle approach in risk management of arsenic is the right thing to do. The Bangladesh experience is a lesson for all policy makers and those in the public health field to keep in mind in any risk management system.

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