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Review

Arsenic in groundwater of West Bengal, India: A review of human health risks and assessment of possible intervention options

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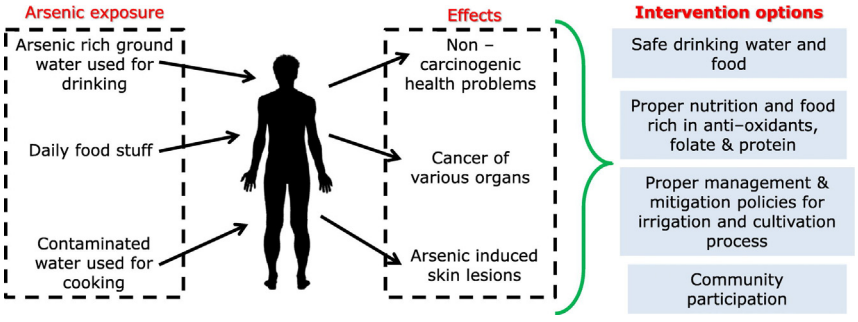
HIGHLIGHTS

- Arsenic poisoning is wide spread in West Bengal and millions of people are at risk.
- Exposure routes are many and are intertwined with the lifestyle of the people.
- Various intervention options to address the arsenic crisis are critically discussed.
- Universal mitigation model may not suite the vast area contaminated with arsenic.

GRAPHICAL ABSTRACT



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ABSTRACT

This paper reviews how active research in West Bengal has unmasked the endemic arsenism that has detrimental effects on the health of millions of people and their offspring. It documents how the pathways of exposure to this toxin/poison have been greatly expanded through intensive application of groundwater in agriculture in the region within the Green Revolution framework. A goal of this paper is to compare and contrast the similarities and differences in arsenic occurrence in West Bengal with those of other parts of the world and assess the unique socio-cultural factors that determine the risks of exposure to arsenic in local groundwater. Successful intervention options are also critically reviewed with emphasis on integrative strategies that ensure safe water to the population, proper nutrition, and effective ways to reduce the transfer of arsenic from soil to crops. While no universal model may be suited for the vast areas of the world affected with by natural contamination of groundwater with arsenic, we have emphasized community-specific sustainable options that can be adapted. Disseminating scientifically correct information among the population coupled with increased community level participation and education are recognized as necessary adjuncts for an engineering intervention to be successful and sustainable.

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1. General introduction

In India, the geogenic arsenic problem is spread over a large geographical area and arsenic contaminated groundwater has been reported for the states of Assam, Bihar, Chhattisgarh, Uttar Pradesh, and West Bengal (Chakraborti et al., 2004, 2013; Nickson et al., 2007). The contaminated areas lie in the vast alluvial plains and delta of the Ganges-Brahmaputra river system which encompasses the Bengal Delta Plain (Chakraborti et al., 2004). Besides Bangladesh, West Bengal has been a core study area for arsenic research and large volumes of data have been generated on geogenic sources of groundwater arsenic, potential arsenic exposure in the populations, and the risk characterization from analysis of various biomarkers. This paper provides a summary of findings from studies carried out in last two decades and discusses intervention options that can be used to address the crisis of arsenic poisoning in West Bengal.

Arsenic is probably the only element in the periodic table that has been the centre of controversy for thousands of years. In the middle age and Renaissance, because of the frequency of use and involvement in many high profile murders, arsenic gained remarkable popularity as an efficient homicidal and suicidal agent; the "King of Poison". The use of poison by the Medici and Borgia families to eliminate their rivals, and the death of Napoleon Bonaparte were all suspected to be due to arsenic (Cullen, 2008; Nriagu, 2002). Since it is odorless and tasteless, and therefore difficult to detect, arsenic was easily used to poison foods and beverages. Because the symptoms such as nausea, diarrhea, abdominal pain were similar to other common diseases at that time, arsenic poisoning often went undetected (ATSDR, 2007). On the other hand, arsenic has also been used to treat certain ailments. The famous "Fowler solution" which contained 1% solution of potassium arsenate has been widely used to treat diseases such as, malaria, asthma, syphilis, eczema, and chorea (Nriagu, 2002). Arsenic paste was used to treat skin and breast cancer, while arsenic trioxide is been used as a chemotherapeutic drug for treatment of acute promyelocytic leukemia (Zhang et al., 2001). The use of arsenical compounds for wallpaper pigment (Paris Green), insecticides and pesticides, wood preservatives (Chromated Copper Arsenate) further elevated the importance of arsenic in daily lives of people (Hughes et al., 2011). Thus arsenic has been a strange element – useful yet poisonous. It is remarkable that although the familiarity of mankind with arsenic dates back thousands of years, the human history remains closely intertwined with that of arsenic and there is still no cure for arsenic malady.

Today, the face of this insidious poison has changed and worldwide, there are millions of people who are being continuously exposed to various concentrations of arsenic, mainly from their drinking water and food (Nriagu et al., 2007). Long term arsenic consumption may give rise to several human diseases which can include reproductive, neurological, cardiovascular, respiratory, hepatic, hematological, and diabetic effects in humans (Mandal and Suzuki, 2002; Rahman et al., 2009). Arsenic is also carcinogenic and has been documented to cause skin, bladder, and lung cancer (Guha Mazumder and Dasgupta, 2011; Rahman et al., 2009). Among the adverse health effects, the most common clinical manifestation of arsenic is the presence of characteristics skin lesions (melanosis, leucomelanosis, and keratosis) and these are considered as an early manifestation of arsenic toxicity (Guha Mazumder et al., 1998c; Saha, 2001). The exact mode in which arsenic exert its toxic effect in humans is complex and, even after years of research, has still not been clearly elucidated. The several proposed mode of action for the disease end point following arsenic exposure has been reviewed in a number of publications (e.g. Hughes et al., 2011; Platanias, 2009; Schumacher-Wolz et al., 2009).

There exists clear differences in the toxicities of the various arsenicals and it has been generally accepted that the trivalent species [arsenite (As^{III}), monomethylarsonous acid (MMA^{III}), dimethylarsinousacid (DMA^{III})] are more potent cytotoxicants than their pentavalent counterparts [arsenate (As^{V}), monomethylarsonic acid (MMA^{V}), dimethylarsinicacid (DMA^{V})] (Mass et al., 2001; Styblo et al., 2000). The orally administered As^{III} and As^{V} are methylated to various proportions of mono and dimethyl arsenicals while the DMA^{V} and MMA^{V} are largely excreted unchanged, with a small portion of MMA^{V} converted to DMA^{V} (Cohen et al., 2006). Arsenobetaine and arsenosugars are the non-toxic forms of arsenic and upon ingestion, arsenobetaine are excreted unchanged, but the arsenosugars are metabolized to various compounds including DMA^{V} (Francesconi et al., 2002; Raml et al., 2005).

Arsenic poisoning has been common, sometimes pandemic, and has interfered with the public health from ancient times to modern times (Nriagu, 2002). The untold suffering of millions of people has mainly been due to humans' large scale meddling with the natural reserve and thereby making ways for several routes in which arsenic may integrate itself with the daily lives of the people. The quest to unravel the presence of arsenic in our air, water and food has led to the development of various scientific disciplines such as analytical chemistry, forensic science and toxicology, and such fascination towards arsenic persists till today. This review is a story of how studies in West Bengal, India have helped to unmask an epidemic of this silent poison.