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Arsenic appearance in groundwater : A forthcoming danger in agriculture

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Arsenic is a semi-metallic element –although it is generally referred to as a heavy metal-that occurs naturally in the earth's crust and has no perceptible taste or odor. In its pure element state, arsenic has a grey colour and is relatively solid. Arsenic is a chemical element with the symbol "As". Arsenic is recognized as a poison and cancer causing substance (carcinogen). It occurs within organic compounds (combined with hydrogen and carbon), and within inorganic compounds (combined with sulphur, chlorine or oxygen). In water arsenic has no smell or taste and can only be detected through a chemical test. When arsenic combined with other elements in the environment, it changes to a powder form that is either white or colourless and is very difficult to distinguish. This, along with its lack of smell and taste, makes arsenic compounds in water, air, or on food extremely hard to detect. Traces of arsenic can be found in air, soil, water and food. Though naturally occurring arsenic in the soil is usually only found in very low concentrations, some regions of the world contain arsenic –heavy deposits, which have been estimated to tremendously increase arsenic levels in the ground. These arsenic-rich areas have frequently contaminated groundwater supplies, which are often the only source of drinking water for local communities. 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. It is a high profile problem due to the use of deep tube-wells for water supply in the Ganges Delta, causing serious arsenic poisoning to large numbers of people. A 2007 study found that over 137 million people in more than 70 countries are probably affected by arsenic poisoning of drinking water. Arsenic contamination of groundwater is found in many countries throughout the world, including USA.

Area of appearance : In India, since the groundwater arsenic contamination was first surfaced from West Bengal in 1983, a number of other states, namely, Jharkhand, Bihar, Uttar Pradesh- in flood plain of the Ganga River, Assam and Manipur- in flood plain of the Brahamaputra and Imphal rivers, and Rajnandgaon village in Chhatisgarh state have chronically been exposed to drinking arsenic contaminated hand tube-wells water above permissible limit of 50 ug/L. Many more North –Eastern Hill states in the flood plains are also suspected to have the possibility of arsenic in groundwater. Even with every additional survey, new arsenic affected villages and people suffering from arsenic related diseases are being reported. All the arsenic affected river plains have the river routes originated from the Himalayan region. Whether or not the source material has any bearing on the outcrops is a matter of research, however, over the years, the problem of groundwater arsenic contamination has been complicated, to a large variability at both the local and regional scale, by a number of unknown factors.

Sources of arsenic : There is no proof regarding the natural emission of As in the Ganga –Brahmaputra plains so far. However, the release of arsenic by the natural processes in groundwater has been recognized from the Holocene sediments comprising sand, silt and clay in parts of the Bengal Delta Plains (BDP), West Bengal and in the Gangetic plains of Bihar. Several isolated geological sources of As have been recognized, *viz.,* Gondwana coal seams in Rajmahal basin, Bihar mica-belt, pyrite-bearing shale from the Proterozoic Vindhyan range, Son valley gold belt and Darjeeling Himalayas belt. The contaminated aquifers are of Quaternary age and comprise micaceous sand, silt and clay derived from the Himalayas and basement complexes of eastern India. These are sharply bound by the River Bhagirathi-Hooghly (distributary of the River Ganges) in the west, the rivers, Ganges and Padma in the north, the flood plain of the River Meghna (tributary of the River Padma), and the River Yamuna in the northeast. The actual source of groundwater arsenic contamination, in the Ganga-Brahmaputra basin, is yet to be established. The sources of arsenic are natural or may partly stem from anthropogenic activities like intense exploitation of groundwater, application of fertilizers, burning of coal and leaching of metals from coal-ash tailings. The main anthropogenic sources for contamination of groundwater with As are mining, burning of fossil fuels, use of arsenical fungicides, herbicides and insecticides in agriculture, and wood preservatives. Burning of coal has profound effect on contamination of As in the environment. Emission of As takes place in the environment by volatilization of As_4O_6 due to burning of coal, which condenses in the flue system and ultimately transferred into water reservoirs. The degree of groundwater arsenic contamination by aforesaid anthropogenic sources is much less as compared to the natural sources; however, their contribution cannot be neglected The hypotheses about the sources of arsenic in the BDP are as follows: (a) Arsenic, transported by the River Ganges and its tributaries from the Gondwana coal seams in the Rajmahal trap area located at the west of the basin can be of the order of 200ppm, (b) Arsenic is transported by the north Bengal tributaries of Bhagirathi and Padma from near the Gorubathan base–metal deposits in the eastern Himalayas, (c) Arsenic is transported with the fluvial sediments from the Himalayas. This is the most accepted hypothesis at present.

Arsenic minerals : Several natural and anthropogenic sources are deemed responsible for As contamination in groundwater. As occurs as a major constituent in more than 200 minerals and the desorption and dissolution of naturally occurring As bearing minerals and alluvial sediments result in high As concentration in groundwater in deltas and alluvial plains even if the As concentration in the solid phase is not high. The presence of metalloid in excess concentration in groundwater may be associated with ore deposits where As is present predominantly in sulfidic minerals such as arsenopyrite and pyrite. Arsenopyrite (FeAsS) is the most abundant As containing mineral generally existing in anaerobic environments and in various other rock forming minerals like sulfide, oxide, phosphate, carbonate, and silicate. It is present as a substitute of S in the crystal lattice of various sulfide minerals. Realgar (As_4S_4) and orpiment (As_2S_3) represent the two common reduced forms of As while in arsenolite (As_2O_3), As is present in oxidized form. Depending on the nature and texture of minerals, As can also be found in sediments, in the concentration range from 3 to 10 mg. The areas with high concentrations of Fe oxide or hydrous metal oxide or pyrites contain very high levels of As in sediments in comparison to other oxides.

Speciation of arsenic compounds in water: Arsenic contaminated water typically contains arsenous acid and arsenic acid or their derivatives. Their names as “acids” is a formality, these species are not aggressive acids but are merely the soluble forms of arsenic near neutral pH. These compounds are extracted from the underlying rocks that surround the aquifer. Arsenic acid tends to exist as the ions $[HAsO_4]^{2-}$ and $[H_2AsO_4]^{-}$ in neutral water, whereas arsenous acid is not ionized.

Problems arise due to arsenic appearance in ground water :

Industrial process : Though there is no specific industrial process that creates this kind of arsenic pollution, the amount of arsenic that leaches from the earth’s crust into groundwater systems can be exasperated by human activity. In many parts of the world, groundwater systems are the only source of water for local communities, and this water is extracted from deep in the earth’s surface using pump wells. Water from these wells is used for a variety of purposes, including irrigation for agricultural fields. Over-pumping of water for agriculture has been blamed for pulling higher concentrations of natural arsenic into groundwater systems, which contaminates entire water sources.

Global context : The areas throughout the world that have the worst documented contamination of groundwater by arsenic are in South Asia, and the toxin poses a frequent problem in Nepal, India, and Bangladesh. According to a report by the WHO, “Bangladesh is grappling with the largest mass poisoning of a population in history” due to arsenic contamination in groundwater, with an estimated 35 to 77 million people at risk. Because arsenic contamination in Bangladesh has been the focus of many other agencies, including the WHO.

Exposure pathways : The most common way that people are exposed to arsenic contamination is through ingestion. The arsenic-laden water is often directly used for drinking, but can also contaminate crops when it is used for irrigation purposes.

Health effects : Arsenic is known to be a dangerous toxin that can lead to death when large amounts are ingested. Small amounts of arsenic exposure over long periods of time can also lead to numerous health problems, including Artisanal Gold Mining, Mercury Pollution, Industrial Estates, Agricultural Production Pesticide Pollution, Lead Smelting, Lead Pollution, Tannery Operations, Chromium Pollution, Mining and Ore Processing, Lead-Acid Battery Recycling, Arsenic in Groundwater, Arsenic Pollution, Pesticide Manufacturing and Storage Pesticide Pollution.

Few of human problems are abnormal heart beat, damage to blood vessels and a decrease of red and white blood cells, nausea and vomiting, and clearly visible irritations of the skin. A common effect of arsenicosis, or arsenic poisoning, is dark patches of skin, corns, or warts on the body. Arsenic is also a documented human carcinogen, and exposure over long periods has been found to cause cancer of the bladder, skin, lungs, kidney, and liver. Various types of skin manifestations and other arsenic toxicity were observed from melanosis, keratosis, hyperkeratosis, dorsal keratosis, and non pitting edema to gangrene and cancer. Overall prevalence of clinical neuropathy was noted in various studies in populations of 24-Pargana-North, 24-Pargana-South, Murshidabad, Nadia and Bardhaman districts of West Bengal and in the states of Bihar, Uttar Pradesh, Jharkhand and Chhattisgarh. Most of the population suffering from arsenic skin lesions is from a poor socio-economic background. The following features were commonly noted (1983-2006) from the arsenic endemic areas of India.

– Skin itching to sunrays, burning and watering of eyes, weight loss, loss of appetite, weakness, lethargy and easily fatigued limited the physical activities and working capacities.

– Chronic respiratory complaints were also common. Chronic cough with or without expectoration was evident in more than 50%.

– Gastrointestinal symptoms of anorexia, nausea, dyspepsia, altered taste, pain in abdomen, enlarged liver and spleen, and ascites (collection of fluid in abdomen).

– Moderate to severe anemia was evident in some cases.

– Conjunctival congestion, leg edema was less common.

Water that contains arsenic is only a concern if it is being used for drinking or food preparation. Exposure through breathing and skin contact is not considered significant or harmful. Ingested arsenic is transmitted through the blood stream and may concentrate within the internal organs, skin, hair and nails. It is eliminated from the body mainly in urine. Exposure to high levels of arsenic can cause short term or acute systems, as well as long term or chronic health effects. Symptoms of exposure to high levels of arsenic may include stomach pain, vomiting, diarrhea and impaired nerve function that may result in "pins and needle" sensation in hands and feet. Arsenic can also produce a pattern of changes in skin which includes darkening of wart-like growths –most frequently found on the palms or soles. The children in the arsenic contaminated areas are often more affected than the adults, because children tend to drink more water per unit of body weight than do adults they may have a greater exposure to arsenic from drinking water and as result be at increased risk of adverse effects when elevated concentrations of arsenic are present. Long term (years to decade) exposure to even relatively low concentrations of arsenic in drinking water can increase risk of developing certain cancers including skin, lung, kidney and bladder cancer.

Effects on agriculture : Agricultural water requirements in most of the rural areas are met from groundwater source. In arsenic affected areas often arsenic contaminated groundwater is used for agricultural irrigation resulting in excessive amount of available arsenic in the crops in those areas. Many researchers reported that food is the second largest contributor to arsenic intake by people after direct ingestion of arsenic contaminated water. In food, rice is the maximum sensitive to arsenic followed by vegetables. Most of the arsenic affected states use rice as its staple food. Recently, possibility of arsenic exposure through food chain is also considered not only in contaminated areas but also in uncontaminated areas due to open market. This eventually indicates that the effects of this occurrence have far-reaching consequences; sooner we search sustainable solutions to resolve the problem, lesser be its future environmental, health, socio-economic and socio-cultural hazards.

Possible solutions to combat arsenic appearance in ground water : Technological options to combat arsenic menace, in groundwater, to ensure supply of arsenic free water, in the affected areas. can be one of the followings or a combination of all.

– *In situ* remediation of arsenic from aquifer system.

– *Ex-situ* remediation of arsenic from tapped groundwater by arsenic removal technologies.

– Use of surface water source as an alternative to the contaminated groundwater source,

– Tapping alternate safe aquifers for supply of arsenic free groundwater.

In situ remediation of arsenic from aquifer system or decontamination of aquifer is the best technological option. Ex-situ remediation of arsenic from tapped ground water, by suitable removal technologies, seems to be a short-term option to provide potable arsenic free groundwater for domestic use only. Although the use of surface water sources, as an alternative to the supply of treated contaminated groundwater, seems to be a logical proposition, it would require availability and supply of surface water flow and organized water supply system for ensuring supply of both drinking and irrigation water. Tapping alternate safe aquifers, for supply of arsenic free ground water, could also prove to be logical proposition. This has also been explored in many areas on a local scale.

Conventional arsenic removal technologies : A variety of treatment technologies, based on oxidation, co-precipitation, adsorption, ion exchange and membrane process, has been developed and are available for removal of arsenic from contaminated water. However, question, regarding the efficiency and applicability/appropriateness of the technologies, remains, particularly because of low influent arsenic concentration and differences in source water composition.

Innovative technologies : Innovative technologies such as permeable reactive barriers, phyto-remediation, biological treatment and electro-kinetic treatment, are also being used to treat arsenic contaminated water, waste water and soil.

Waste disposal and sludge management : Waste disposal is an important consideration in the treatment selection process. Arsenic removal technologies produce several different types of waste, including sludge, brine streams, backwash slurries and spent media. These wastes have the potential for being classified as hazardous and can pose disposal problems. According to the study conducted by All India Institute of Hygiene and Public Health (AIIH and PH), arsenic rich sludge may be disposed by the following methods: (1) disposal in on-site sanitation pits, (2) mixing with concrete in a controlled ratio, (3) mixing with clay for burning for brick manufacturing.

A technique to solve problem : It has been proved that arsenic has affinity with iron in groundwater both positively and negatively, depending upon the condition. There is wide scale report of the presence of dissolved iron, in arsenic contaminated groundwater, and of co-precipitation of iron and arsenic under oxidizing condition. The relationship between As-Fe can be interpreted as signifying that in these instances iron played the scavenger role, adsorbing arsenic from water as it precipitated out, again desorbing arsenic into water as it re-dissolved in response to appropriate change of Eh-pH conditions. This gives a positive hope of a plausible way of in-situ remediation of the problem of As contamination by removal of Fe from groundwater before withdrawal.

Various available options suited for getting drinking water : The various available options suited for getting drinking water with low As content can be divided into two categories which include (i) finding an alternative As free water source, (ii)removal of As from the existing water source.

Finding an alternative As free water source: Literature reviews from the Bengal and the Mekong deltas insinuate that As-rich water occurs mainly in the shallow groundwater, whereas groundwater from deeper aquifers is almost completely free from As. (a) By constructing open wells, generally called dug wells (DWs) with large diameters, As free safe drinking water can be obtained from As contaminated shallow aquifers. The reasons for the unpopularity of the DWs are obnoxious smell and taste, turbidity, and distance and time bound limitations to fetch water. Bacteriological contamination is the principal problem associated with the use of DWs water, (b) Surface water-ponds, lakes, and rivers are generally low or free of As and can be reintroduced in affected areas as a source of safe drinking water, (c) Reintroduction of surface water as a source of safe drinking water would require antimicrobial treatment like incorporation disinfectants, use of pond sand filters or combined surface water treatment units, (d) Rainwater harvesting-since ancient times, the rainwater harvesting (RWH) has been widely used practice throughout the world as a potential method of utilizing rainwater for domestic water supply. RWH is widely used method at household level globally and there is also an increasing trend on its application at larger community level. The rainwater is safe if it is hygienically maintained and this technology is feasible in areas with average rainfall of 1600 mm/year or more.

Removal of As from the existing water source : (a) Oxidation : The main aim of oxidation is to convert soluble to, which is followed by precipitation of, (b) Coagulation-Flocculation : The incorporation of a coagulant followed by the formation of a floc is a potential method used to remove As from groundwater, (c) Adsorption : Removal of As by adsorption onto activated/coated surfaces is getting popular because of its simpler operation and sludge free day to day operation, (d) Latest advancements on arsenic removal by adsorption: A wide spectrum of different materials have been explored for adsorption of arsenic from groundwater water but iron oxides and oxyhydroxides are the most widely studied and their commercial products already dominate a major portion of the market, (e) Biological arsenic removal : Basic techniques are: (i) Bacteria play crucial role in geochemical cycling of As by oxidation/reduction reactions, such bacteria are known as dissimilatory arsenate reducing bacteria or arsenate respiring bacteria (ARD), for example, *Geospirillum arsenophilus*, *Geospirillum barnesi*, *Desulfutomaculum auripigmentum*, *Bacillus arsenicoselenatis*, and *Crysiogenes arsenates*, (ii) Biological oxidation of can be applied as an alternative to the chemical oxidation. Iron and manganese are typical unwanted constituents in drinking water causing aesthetic problems known to play significant role in arsenic concentrations in groundwater. Specific indigenous bacteria mediating biological oxidation of arsenic are known as "iron and manganese-oxidizing bacteria." These bacteria have been successfully applied for the biological arsenic oxidation directly in continuous groundwater treatment, (iii) The biological oxidation of iron by two bacteria, *Gallionella ferruginea* and *Leptothrix ochracea*, has been found to be a promising technology for effective removal of arsenic from groundwater. In this process, iron oxides are coated on filter medium, along with the microorganisms, which offer an ideal environment for arsenic to be adsorbed and removed from the water.

Conclusion : Arsenic contamination of groundwater is an alarming problem on a global scale. In several parts of the world, biogeochemical processes have resulted in dissolution of naturally occurring As into groundwater. In order to combat arsenic problem, various remediation methods based on conventional, modern, and hybrid technologies for removal of As in several parts of the world are followed. Most of the existing technologies for removal of As involve the direct removal of or converting to followed by removal of. The implementation of mitigation options can be facilitated by setting proper guidelines and to control implementation at appropriate intervals. The awareness of the population is deemed equally important in maintaining and choosing mitigation. However, even for well-aware population, the dilemma is often the ability to meet prohibitive costs versus the wish to improve their situation. For communities public participation encounters the same constraints. Governmental and donor financial and logistic assistance may be essential to reduce arsenicosis. Besides, extensive research should address the understanding of the occurrence, origin, and distribution pattern of arsenic. The government should monitor industrial and agricultural activities leading to As pollution. More technical assistance should be rendered to mining or chemical plants to deal with sewage and sludge storage and waste treatment. Supervision departments should increase the frequency of sampling and analysis of the discharge from industrial plants. Due to the significant and widespread human health problems posed by naturally occurring arsenic in drinking water, much international attention has been paid to this issue, particularly in Bangladesh. Most remediation programs have revolved around identifying and labeling wells with contaminated water, helping communities find safe alternatives for water sources (such as collecting rain water), and implementing low-cost water treatment systems. There are several challenges for agriculture development in our country (*i.e.* population explosion, diminishing per capita land holding, lack of irrigation water, lack of proper marketing infrastructure, low price of produced agricultural products, deterioration of soil health day by day, soil erosion, lack of proper storage facility of agricultural products those are perishable in nature, lack of electricity of irrigation, spoiling of foodgrains in FCI godowns due to improper management, lack of proper INM, IWM, IPM measures, unavailability of agricultural inputs, lack of good quality seed, problem due to particular crop's excess production, lack of proper transport facility, middlemen problem, lack of quality agricultural produces etc.) and arsenic appearance in groundwater has introduced a new challenge in Indian agricultural diasporas. Arsenic appearance in ground water is making water unfit for irrigation. Lack of sufficient amount of irrigation water is a problem in our country and whatever the irrigation water is available, the arsenic appearance day by day making it unfit for irrigation. Therefore, a forthcoming danger is hidden in incident of arsenic appearance in ground water. On the other hand, presence of arsenic in human body is seen through drinking water as well as through consumption of food crops those are irrigated by arsenic affected water. Arsenic appearance in human body invites many diseases and deadly diseases, which is obviously a great concern of National Health Mission. Therefore, the time has come to focus more on this aspect very seriously; otherwise this slow and steady silent killer will surely engulf the health of our nation. Hence, government must take various proactive measures through research and extension activities instead of post-active measures to eradicate such a menace from our country forever.

"When the natural resources of any nation become exhausted, disaster and decay in every department of national life follow as a matter of course. Therefore, the conservation of natural resources is the basis, and the only permanent basis, of national success." –Gifford Pinchot.

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