

GEOLOGICAL CONTAMINATION OF ARSENIC IN GROUND WATER: A REVIEW

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ABSTRACT

The quest for the stability of life has lead mankind to play with his own life by poisoning his body in the name of fertilizers, herbicides, and pesticides. The drive for higher yield has ultimately poisoned the land making it redundant for time uncalculated. But man did not stop here. He went on to harvest the underground resources at a speed which only spells of greed. This greed resulted in not just the depletion of resources but also poisoning them to a level that turned it carcinogenic. Arsenic poisoning is posing a huge menace for the mankind and rapid industrialization may culminate in the extinction of mankind himself. It is the time that steps are taken to curb and control this menace.

Keywords: Arsenic, Geological, Ground Water, Heavy metals, and Co-precipitation.

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INTRODUCTION

Arsenic is posing serious health hazards in most parts of the folk owing to little knowledge on its treatment. Isomers of As are more contagious than organic arsenic. Arsenic is found as its pentavalent isomer in the environment aerobic condition.

As contaminated water can be diluted into groundwater system since it is mobilized in groundwater as well as aquifers. This process of contamination can harm a large chunk of the population.¹

Analysis of arsenic has revealed a constituent growth in the concentration of As and its isomers in groundwater, the sources of the arsenic mineral are presented in Table-1. The concentration of As has been found to be in the hazardous range in more than half of the civilized countries.

Table-1: Arsenic Sources in Earth Minerals

| S.No. | Arsenic Minerals | Chemical Formula | Sources |
|-------|------------------|--|--|
| 1 | Arsenic | As | Hydrothermal Veins |
| 2 | Realgar | AsS | Vein deposits, deposit from hot springs |
| 3 | Orpiment | As ₂ S ₃ | Hydrothermal veins, hot springs, volcanic sublimation products |
| 4. | Cobaltite | CoAsS | High temp. deposits |
| 5. | Arsenopyrite | FeAsS | Mineral Veins |
| 6 | Enargite | Cu ₃ AsS ₄ | Hydrothermal Veins |
| 7. | Arsenolite | As ₂ O ₃ | Oxidation of Arsenopyritenative Arsenic |
| 8 | Scorodite | FeAsO ₄ .2H ₂ O | Secondary Mineral |
| 9. | Anabergite | (Ni,Co) ₃ (AsO ₄) ₂ .8H ₂ O | Secondary Mineral |
| 10. | Tennantite | (Cu,Fe) ₁₂ As ₄ S ₁₃ | Hydrothermal Veins |

[Adapted from "Arsenic in Australian Environment: An Overview," by Smith J, Smith E, Biswas T, Naidu R and Correll R 2003, J. Env. Sci. and Health, 33, 223-239 and Arsenic Toxicity: Prevention and Treatment (2015)CRC Press, Taylor & Francis Publishers.]

The Gangetic and Brahmaputra alluvial plains have arsenic contamination more so on account of fertilizing residues. The Holocene aquifer along fluvial tracks Brahmaputra barrack valley is yet to be recognized but the sulfide belts of Bihar, UP and North Bengal to coal seams of Gondwana basins. The rajmahal tracks along with metamorphic cist of the lesser Himalaya may have a possible role in triggering arsenic reactions. Redox potential, adsorption, and pH competing for ions etc influence perturbation of arsenic resulting in a concentration in one place and scarcity at the others. Arsenic concentration diminishes downwards and brings a geochemical perception lends a major help in the development of *in situ* of arsenic². The As-Fe relationship is a significant one as Fe plays the role of scavenger in absorbing arsenic (As) from water as well as dissolving arsenic into the water. Linear track of river coarses are the worst affected river water has the specific and unique property of filtering, storing and transmitting that keeps it free from Arsenic.

Arsenic has been known to occur as a compound with more than 200 mineral which is partially or fully water soluble as a result of which the contamination of groundwater cannot be controlled. As bearing mineral and sediments creates a high arsenic concentration in groundwater in deltaic and alluvial plains as a result of desorption and dissolution.^{3, 4}

As is predominantly present in areas which abundance in the pure deposit which can be a plausible reason for the presence of metalloid in excessive concentration in groundwater and more so in sulphidic minerals as pyrites.⁵

Arsenic is found in abundance as Fe As S and primarily existing in aerobic environments apart from other rock-forming minerals. Contamination in groundwater exceeds hazardous limit owing to oxides of iron and Al whose sediment play a significant role.^{6, 7}

The activity of indigenous metal-reducing bacterial coupled with the reductive dissolution and mobility of arsenic has been greatly affected by these Fe and Al oxides.⁸

Mining, fossil fuels, fungicides, Herbicides, insecticides and wood preservatives are the principal anthropogenic sources for groundwater pollution. Combustion of coal results in As contamination in the environment. Volatilization of As_4O_6 as a result of heat releases nascent arsenic in the environment. However, the effect of fuel system results in transferring this nascent arsenic into water reservoirs.⁹

Arsenic is found in two oxidation states in the groundwater i.e. Arsenite and Arsenate. These anions represent the state. The isomers of arsenic exist in the pH range 6-9. Trivalent arsenic species are common and uncharged as H_3AsO_3 while the pentavalent species are actually monovalent and divalent derived of either isomer can be the outcome of geology and groundwater environment.^{10, 11}

Local researchers have proved that arsenic has an important role in explaining and understanding the behavior and characteristics in the eminent. However, there is marked the difference between the trivalent and pentavalent isomers as regards the toxicity and removability. The variation in the content of groundwater varying in the arsenic content of aquifer and other dissolution desorption process that release arsenic into the liquid in the environment. Which release arsenic into liquid phase? It has been inferred that reduction dissolution of iron oxides is a primary cause of arsenic release from aquifer sediments¹² which is represented in Fig.-1.

The symptoms of arsenicosis depend on the quantity ingested coupled with the nutritional status and immunity of person and may appear in 6- 2 years or more. Poisoning by natural arsenic surfaces in several stages like; Melanosis and keratosis of skin, dark spots on abdomen, limbs, and gums, nonretractable enlargement of liver , kidney and spleen in the long run; patients may show symptoms of nephropathy , hepatopathy, gangrene or cancers of skin , lungs and bladders. Though placed with metalloids, the element may be found as Arsenate, Arsenite, Arsenic, and Arsine. Arsenic is anionic in behavior in aqueous systems.^{13, 14} However, arsenic acid is predominant in oxygenated water at a low pH of less than 2. It undergoes conversion as H_2SO_4 and $HAsO_4^{-2}$ when subjected to the pH range of 2-11. Arsenious acid gets converted to H_2AsO_3 with the increase in pH on natural catalysis of mildly reduced conditions and low pH values. These result in $HAsO_3$ over pH of 12.

The aqueous environment in which the elements are found governs the movement and precipitation of the elements with different valency states that are dependent on oxidation-reduction states.¹⁵

Being characterized by aerobic nature of oxygenated water H_2S surface stream does not exist in unsaturated zone whereas in capillary fringe the upper part is known as a reservoir when insoluble ferric hydroxide is present with soluble arsenate, arsenate dominates. However, pH, temp, exposure to sunlight affects the rate of reaction.¹⁶

Arsenic precipitates as arsenic sulfide and forms arsenic ferrous sulphur ion in anaerobic acidic conditions that may combine with heavy metals in insoluble compounds to form common organic arsenical pesticides that have been reported to oxidize into inorganic arsenate in aerobic and reducing conditions forming volatile arsines. It has been noted that reduced arsenite ion is 60 times more toxic as compare to arsenate ion in oxidized form.¹⁷

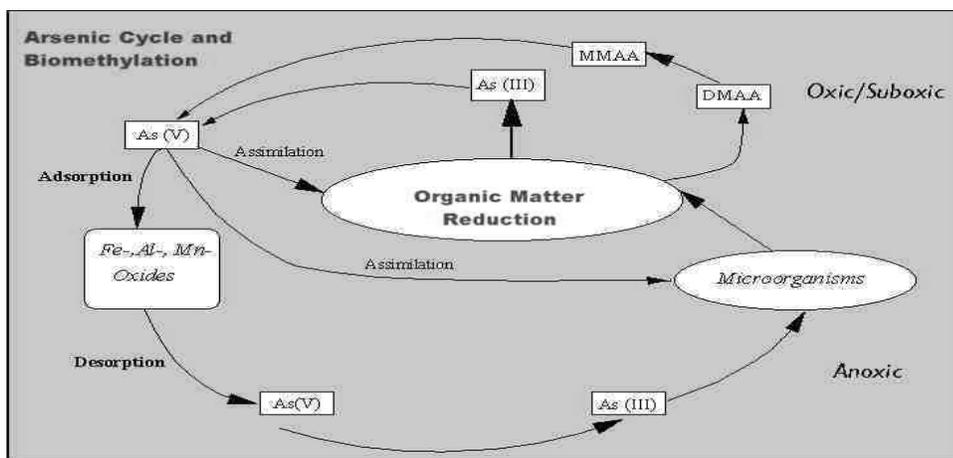


Fig.-1: Arsenic Cycle and Biomethylation

(Source: Prosun Bhattacharya- Arsenic Research and Global Sustainability at 2106 by CRC Press Taylor & Francis Group)

Table -2: Condition influencing Arsenic mobility in environment

| Environmental Conditions | Conditions affect As Mobility |
|---|--|
| Landfill Oxic Water | Arsenate (V) Insoluble $Fe(OH)_3$ H_2S absent |
| Anaerobic Mildly reduced Post Oxic Shallow groundwater | Soluble Arsenite (III) Ferrous ion H_2S absent |
| Anaerobic Reduced conditions Groundwater Reducing bacteria | Insoluble & co-precipitated Arsenic sulfide H_2S Present |

The concentration of Arsenic in the sediments is considered mediocre from 1.7- 400mg/kg. However, areas of high contamination also exist more around industries, mines and mine tailings. Arsenic exhibits anionic behavior and creates arsenic acid in oxygenated water. It predominates only at extremely low pH, arsines derivatives and As Metals may occur under extreme reducing condition. It has been observed that Arsenic is prone to environmental influence and changes its valence and chemical form.

Removal of Arsenic

Many ferrous arsenic removing devices have been developed but satisfactory performances at field level have been restrictive in terms of arsenic removal efficiency as well as sustainable running. Operation maintenance replacement and removal or used filters in most of the devices has been a setback. The

system has shown satisfactory performance when its O & M has been made the responsibility of suppliers. More devices can be developed and applied in other countries supplementing the already existing devices.^{18, 19} Major techniques for removal of Arsenic are oxidation, co-precipitation, adsorption, Ion-exchange and membrane process guide the development of technologies. It is noteworthy that effective system of arsenic removal technologies depends on:

- Use and O & M of the device
- Its removal efficiency
- Its output and cost
- Eco-friendliness of device
- O & M mechanism

Arsenic removal devices based on permutation principles have been put to practical use. However, most of them were far from satisfactory performance or lack in O & M or sludge disposal problem.^{20, 21}

Various studies from the researchers observed that withdrawal of arsenic-free groundwater and in-situ treatment is actually based on recharging groundwater into subterranean aquifers. High level of oxygen controls the release of arsenic from soil. Thus an eco-friendly technique provides safe irrigation at minimal cost. Though, verification and field application has to be tested at large scale implementation²².

Lime softening and iron co-precipitation provide a better effect to removal technologies running satisfactorily but only where O & M was the responsibility of public-private partnership. Though linked to tube well and day to day case O & M has no relation with ARP or its chemical media. Adequate self-maintenance provisions would boost the performance of the devices, training in proper direction coupled with the motivation of user community O & M would be a priority before facilitating any ARP program²³. The prevalent technologies have been found to be affected by treating the arsenates but arsenite is a compound that necessitates time. Some of the technologies include oxidation as a pre-requisites for converting As^{+3} to As^{+5} while as natural oxidation of arsenic is slow and is time-consuming but certainly through certain chemical reactions it oxidized rapidly.

CONCLUSION

The scale of use of ART will indicate the level of complexity to make them suitable and sustainable. As is not found in surface water as such surface water can be used with an insignificant treatment with the help of an organized piped water supply appears cost-effective yet feasible for potable water in West Bengal where surface water availability regulates.

Investigations have shown that Arsenic contamination in deeper aquifers in minimal these being free, from the further threat from contamination shallow aquifer can be a sustainable source of potential groundwater withdrawal. The dissolution of Arsenic mineral generates a major part of arsenic chemical species and the degree of dissolution and its chemical species can be established mathematical modeling. Oxides, hydroxides releases arsenic during deduction-dissolution, co-precipitation and adsorption have an important role in deciding the mobility and fate of arsenic (As). Effect of microbes on arsenic fluxes requires a detailed study.

Localized patches of Arsenic affected areas generate contamination zones. Such areas are free from Arsenic contamination zones. Such areas have negligible arsenic contamination. Most of the freshwater zones are free from including contaminants from infected zones on account of hydrogeological feature and fluvial characteristics. This throws light on tapping shallow freshwater zones. Monsoon replenishes shallow aquifers. As does not contaminate for a long time till catalyzed by natural processes or external intervention linear track of riverbanks are natural treatment installation due to natural properties of filtration, storage and water transportation (transmission).

It is suggested to explore tapping of freshwater should be utilized. The creations of ion and tentative reactions have been explored to lead arena for further research

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