# Arsenic Calamity in West Bengal

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***Abstract:***
***Background****: Arsenic contamination of groundwater in Gangetic West Bengal is a matter of great concern. Groundwater is the main source of drinking and cooking for millions of inhabitant in this part of the world.*
***Method:*** *A literature survey was done to understand the cause of widespread arsenic in the aquifer material when concentrations are typically less than 10 ppm in sandy sediment and less than 100 ppm in clays and peats which is quite unusual. Study was conducted in a small cluster of 5 km$^2$ area having a population of 5000 people in Kasimpore, North 24 Parganas District, West Bengal where samples were taken from different tubewells to measure the arsenic content. The villagers using the tubewells are also examined for any clinical manifestations.*
***Results:*** *The specific hydrological and biochemical seemed to support and contribute to the high concentration of this Arsenic in the aquifers of Gangetic delta in West Bengal. The study indicates 76% of the total tubewells water sample have arsenic above 10 µg/L and poses a grave health hazard. Approximately 15% of the total population in the cluster under study seemed to show clinical manifestation and likely to grow in coming years which is a matter of grave concern.*
***Conclusion:*** *Although novel solutions are being developed by scientific community to remove arsenic from groundwater extracted through tubewells, more attention and efforts are needed to prevent the situation from going out of control leading to health catastrophe.*
***Key Words****: Arsenic, groundwater*

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## I.     Introduction

Arsenic contamination of groundwater is an issue of global concern. Arsenic is a ubiquitous element that ranks 20th in abundance in the earth's crust, 14th in the seawater, and 12th in the human body [1]. Since its isolation in 1250 A.D. by Albertus Magnus, this element has been a centre of controversy in human history. It has been extensively used in medicine [1] as well as in various fields i.e. agriculture, livestock, electronics, industry and metallurgy [2]. It is now well recognized that consumption of arsenic, even at low levels, leads to carcinogenesis [1]. Arsenic is perhaps unique among the heavy metalloids and oxy anion-forming elements in its sensitivity to mobilisation at the pH values typically found in ground waters (pH 6.5–8.5) and under both oxidising and reducing conditions. The concentrations of arsenic in groundwater vary by more than four orders of magnitude (<0.5 to 5000µg/L) depending upon the sources, contents and local geochemical environment [3]. Localised groundwater arsenic problems are now being reported from an increasing number of countries and many new cases are likely to be discovered.

The majority of human populations are exposed to low level of arsenic, principally through both ingestion and inhalation. Arsenic is appearing in the food chain and is widely distributed throughout the plant and animal kingdoms. For example, fruits, fishes and vegetables contain arsenic in organic form, whereas arsenic presents in many other foods (i.e. milk and dairy products, beef and pork, poultry, and cereals) in mainly inorganic forms [4,5]. Inorganic arsenic is metabolized in humans and most rodents to mono-methyl arsenic (MMA) and di-methyl- arsinic acid (DMA). Inorganic arsenic has been described as a paradoxical human carcinogen, with strong evidence of human carcinogen potential [6]. The most frequent health problems associated with chronic high exposures to this element are skin disorders, but cancers of various sites are often observed at later stages as well [7, 8]. Arsenic has also been linked to cardiovascular diseases, reproductive problems and neurologic disorders [9]. The evidence for arsenic carcinogenicity is mostly based on epidemiological studies, which have conducted among arsenic exposed populations in different parts of world. Long-term exposure to arsenic through drinking water has been considered to create cancer of bladder, lungs, skin, kidney, liver, and prostate [10]. Following the accumulation of evidence for the chronic toxicological

effects of as in drinking water, recommended and regulatory limits of many authorities are being reduced. The WHO guideline value for as in drinking water was provisionally reduced in 1993 from 50 μg/L to 10 μg /L.[11].

Arsenic poisoning in West Bengal may be termed as the worst case of mass poisoning in modern times. A rough estimate shows that more than 25 million people are affected due to involuntary arsenic exposure through consumption of drinking water and rice, the main staple food in the region. The primary cause of the problem is very high arsenic content in groundwater, which is used for both drinking and irrigation purposes. Chronic arsenic toxicity causes clinical manifestations e.g. spotty pigmentation of skin of the body, keratosis of palms and soles, chronic lung disease, liver fibrosis, peripheral vascular disease, peripheral neuritis, and cancer of skin, lung, bladder and liver[12]. Lack of proper health risk assessment and poor access to alternative safe water has forced millions in eastern India to use arsenic contaminated water. The current focus of investigations is on the need for remediation of the contaminated groundwater on the assumption that this is the major link between Arsenic and human beings. While such exposure requires immediate attention, it is incumbent upon us to determine the impact of long-term irrigation with as-contaminated groundwater on agricultural soils. Exposure can include incidental ingestion of Arsenic contaminated soil, and ingestion of Arsenic through crops that have been grown on contaminated soil.

Researchers by and large agree that dissolved arsenic in the groundwater of West Bengal has its source from the sediments. However, the evidence of widespread, unusually high levels of solid phase arsenic in the aquifer material where the concentrations are typically less than 10 ppm in sandy sediment and less than 100 ppm in clays and peats [13,14] is absent. High solid-phase concentrations can be found in the soils of irrigated fields, but these could be the result of arsenic input from groundwater irrigation and sorption to the soils [15]. Thus, it is apparent that the high dissolved arsenic concentrations are the result of specific hydrological and biogeochemical conditions that force arsenic from the solid to aqueous phase but have not yet flushed dissolved arsenic from the subsurface.

The conditions of almost all groundwater in West Bengal is reducing in nature. This is well demonstrated by high levels of dissolved ferrous iron and methane, and low measurements of oxygen potential and the weak but statistically-significant positive correlation of dissolved arsenic to iron and bicarbonate. This suggests that most arsenic is liberated by dissolution of iron oxyhydroxides ($FeO(OH)$), or perhaps desorption of arsenic after reduction from arsenate to arsenite [16]. The low concentrations of sulphate (and in some areas the negative correlation between arsenic and sulphate) as well as the generally reducing conditions in the aquifer indicate that arsenic is not directly mobilized from sulphide minerals [7]. However, the arsenic in the Ganges Delta sediments likely originated from sulphide minerals that weathered out of the granitic and metamorphic source rock of the Himalayas, and it remains a possibility that at the land surface, where oxygen is introduced as the water table rises and falls as the aquifers recharged or emptied, sulphide minerals could be oxidized and get dissolved thereby liberating arsenic in the system. The long-term implications of such cyclical near-surface processes in a rapidly build up ($\sim 1$ cm/yr) aquifer remain to be studied. Several research teams [15,17] have come across two distinct types of aquifer sediment: brown (or orange to yellow) sediment presumably containing iron oxyhydroxides ($FeO(OH)$) where dissolved arsenic concentrations are low, and grey sediments where dissolved arsenic concentrations may be high. The brown sediments are predominant at depth in the older Pleistocene aquifers such as the Dupi Tilla formation as well as near the surface where low arsenic water is found. Dissolved arsenic is presumably low in these sediments because iron oxyhydroxides has the capacity to adsorb arsenic. Islam et al. [18] showed that arsenic get liberated from sediments collected in West Bengal by the addition of organic carbon. They do not report the in-situ arsenic concentration in the pure water, but the sample contains iron oxyhydroxides and is described as coming from a transition zone between a region of oxidizing conditions and a region with reducing conditions. The role played by iron oxyhydroxides within the contaminated grey sediments of the Holocene aquifer, where most wells withdraw water, is much more baffling. If the theory that arsenic is released from iron oxyhydroxides in local sediments by organic carbon oxidation is true, then iron oxyhydroxides must exist, or have existed very recently. However these iron oxyhydroxides have not been definitively demonstrated in the grey sediment and high concentrations of methane and hydrogen [19] in strongly reducing water indicate that geochemical conditions are not conducive to stability of iron oxyhydroxides. On the other hand, Swartz et al. [19] show that only small quantities of iron oxyhydroxides would be required to explain current geochemical conditions. McArthur et al. [13] provides a geologic explanation for why the Ganges Delta sediment would have been deposited with relatively little iron oxyhydroxides. Thus, it is conceivable that slow reductive dissolution within aquifer sediments could be responsible for high dissolved arsenic concentrations, but only if the geochemical system happens to be in a state where iron oxyhydroxides have released almost all of their adsorbed arsenic. To be put it differently, the aquifer sediments must be poised in a geochemical state where the inventory of iron oxyhydroxides is nearly (or recently) exhausted, yet arsenic has not been flushed away by flowing groundwater. Other explanations are that both the physical flow system and the biogeochemical system have recently been unsettled, and that dissolved arsenic originates from near-surface sediments above the aquifer. Dissolved arsenic concentrations are

maintained in grey sediment because several geochemical factors conspire to prevent arsenic that has been dissolved from sorbing back onto this aquifer sediment. First, the paucity of ferric oxyhydroxides means there are few adsorption sites. Second, high concentrations of other anions, such as silicate and phosphate, which compete with arsenic for surface adsorption sites, are prevalent in groundwater throughout most of the arsenic-affected areas. However, there is no convincing correlation between these anions and arsenic to indicate that these anions explain the spatial pattern of dissolved arsenic. Appelo et al. [20] have also suggested that competition by bicarbonate, which correlates better with arsenic, might explain the distribution of dissolved arsenic. By this scenario, oxidation of organic carbon liberates arsenic indirectly through desorption caused by its by product, bicarbonate, rather than directly by reduction of iron oxides or arsenate. However, equilibrium chemical modelling using the parameters measured at various site indicates that the effect of bicarbonate on arsenic adsorption is less than that of silicate and no more than phosphate [19]. These conceptual geochemical models are further complicated by the fact that arsenic likely adsorbs to surfaces of many solid phases other than oxyhydroxides, such as magnetite, green rust, and potentially siderite and apatite. Arsenic is known to adsorb readily to magnetite [21]. Several research groups postulate that irrigation pumping may flush arsenic from aquifers [13,17]. Harvey et al. [17] support this contention by comparing concentrations sampled from irrigation wells to concentrations from drinking water wells to show that irrigation wells, which flush much greater quantities of water, have significantly lower arsenic concentrations. Ali [22] estimated that groundwater irrigation removes 1 kg arsenic per hectare of irrigated land by applying to crops in the field. Thus, irrigation pumping would have extracted much more than a million kilograms of arsenic per year from the aquifers and moved it into rice fields. On the other hand, some evidence suggests that arsenic concentrations may rise after pumping commences. Kinniburgh et al. [23], van Geen et al. [24], and McArthur et al. [13] all provide strong statistical evidence that arsenic concentrations in domestic well water correlate to the age of the well, suggesting that arsenic concentrations may rise after a well is installed, perhaps because irrigation wells, which have much greater effects on the local groundwater system, are installed in the region at the same time as the domestic wells where arsenic is measured. However, increased flushing may be concurrent with increased arsenic input either by simple transport or release caused by input of organic carbon from the surface sources, or potentially drawn from peat layers. This concurrent enhancement of both sinks and sources of arsenic to the groundwater system by human perturbation could potentially create very complex temporal and spatial distribution of dissolved arsenic.

## II. Material And Method:

The study was conducted in Kasimpore, a village in North 24 Parganas District, in the Ramakrishna Mission premises, approximately 25 km from Kolkata. The total area of the village is 5.0 km2 , and the average annual income of the villagers is Rs 24850/annum. Study was done between 1st January 2000 to 31st December 2006.

The main source of water for the village is shallow wells and tube wells. Kasimpore was chosen as the model village in our study since our preliminary study revealed that 70% of the tube wells in this village had arsenic concentrations above 50.0 mg/L as compared to the WHO guideline value of 10 mg/L. The area of study belongs to the lower Gangetic plains of India, where arsenic contamination has reached an alarming level. According to one estimate, nearly 100 million rural people are affected by exposure to Arsenic in food chain and drinking water in Asia

Forty surface (0 –20 cm) soil samples were collected and brought to the laboratory in properly labelled and sealed polythene bags. Microbiological and biochemical analyses were performed with the field moist soils. Physico-chemical analyses were carried out with air-dried soil samples. Chemical, microbiological and biochemical parameters were expressed on moisture free basis. The physico-chemical analyses were carried out with the air-dried soil samples. The pH was determined in a 1:2.5 soil/ water suspension [25] while sand, silt and clay percentages by International Pipette Method [26]. Organic carbon was determined by Nelson and Sommers (1982) [33]. Total arsenic were determined by the method of Page et al. (1982) [26] and sodium bicarbonate (NaHCO3) extractable and water-soluble arsenic were determined by the method Johnston and Barnard (1979) [27]. Microbial biomass-C and N were measured by fumigation extraction method followed by determination of ninhydrin reactive N (Jenkinson, 1994)[31]. Soil respiration (basal and SIR) was determined following the method of Alef (1995) [32]. Fluorescein diacetate activity of the soil was determined by the method described by Schnurer and Rosswall (1982)[28]. Dehydrogenase activity was determined by the method of Casida et al. (1964)[29]. Data in Tables 1 and 2 are expressed as mean of 10 samples from each site.

Some remedial measures are introduced in the site such as subterranean groundwater treatment by the in situ method [30] using atmospheric oxygen as the oxidising agent . In this method the groundwater treatment takes place underground. The success of the treatment depends largely on the soundness of the process and the knowledge of the geochemistry of the aquifer. In situ chemical oxidation is based on the delivery of chemical oxidants to contaminated media in order to destroy the contaminants by converting them to innocuous

compounds commonly found in nature. The oxidants applied in this process are typically hydrogen peroxide ($H_2O_2$), potassium, permanganate ($KMnO_4$), ozone ($O_3$) and dissolved oxygen (DO).

**Result and analysis**

Arsenic in hand tubewells water, total number of hand tubewells and an estimation of population drinking arsenic contaminated water at various concentration levels in Kasimpore block A detailed study report of the groundwater arsenic contamination is presented in Table 1.

Fig. 1 shows the arsenic contamination status in the measured 30 hand tubewells of the Kasimpore block. The bar diagram of the concentration ranges of arsenic against the percent of water samples of the Kasimpore block is presented in Fig. 1. From the analysis results of water samples, it appears that 76% of water samples contain arsenic at concentration above 10μg/L, 51% contain above 50μg/L and 22% above 300μg/L, the concentration predicting overt visible arsenical skin lesions. On the basis of the information (number of users per tubewell) we gathered during our collection of 50 water samples from Kasimpore clusters, it appears that on average 30 people use one hand tubewell. Based on this we expect approximately 167 hand tubewells to exist in the block. We have analyzed about 30% of all the hand tubewells in Kasimpore block. Table 2 shows the expected population in Kasimpore block drinking arsenic contaminated water at various concentration levels of arsenic. We have calculated the expected number of people drinking arsenic contaminated water at various levels of arsenic concentration on the basis of the percentage of hand tubewells having arsenic above different concentration levels, which we expect directly related to the population. This estimation is based on the extrapolation of the 30% of the total hand tubewells analysed.

**Table 1** Typical Groundwater analysis at the test site before the experiment

| Parameters | Analysis | Permissible limit |
|---|---|---|
| pH | 7.3 | 6.5-8.5 |
| Turbidity (NTU) | 1.7 | 10 |
| Conductivity (μmhos/cm) | 914 | - |
| Total Dissolved Solid (TDS) (mg/L) | 594 | 2000 |
| Dissolved Oxygen (DO)(mg/L) | 2.7 | - |
| Chloride (as Cl) (mg/L) | 20 | 1000 |
| Total alkalinity (as $CaCO_3$) (mg/L) | 530 | 600 |
| Total Hardness (as $CaCO_3$) (mg/L) | 420 | 600 |
| Sulphate (as $SO_4$) (mg/L) | 2.0 | 400 |
| Nitrate (as N) (mg/L) | 6.12 | 100 |
| Iron (as Fe) (mg/L) | 0.88 | 1.0 |
| Mn (mg/L) | 0.7 | |
| Arsenic (as As) (mg/L) | 0.037* | |

*Arsenic contamination is well above the WHO recommendation of 0.01 mg/L.

**Table 2 :** Detailed study report of Kasimpore North 24 Parganas district

| Physical parameters | Kasimpore |
|---|---|
| Area in km2 | 5 |
| Population (according to 2001 Census) | 5000 |
| Number of hand tubewells water samples analyzed | 50 |
| Number of villages surveyed | 5 |
| Percentage of samples having arsenic above 10 μg/L | 34 |
| Percentage of samples having arsenic above 50 μg/L | 20 |

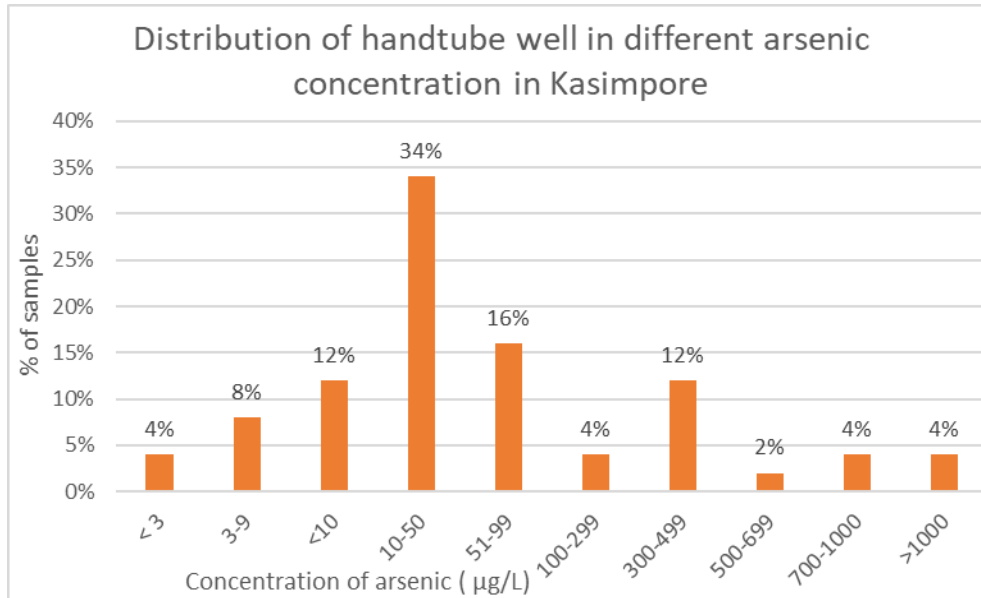| | |
|---|---|
| Percentage of samples having arsenic above 300 μg/L | 12 |
| Percentage of samples having arsenic above 500 μg/L | 6 |
| Percentage of samples having arsenic above 1000 μg/L | 4 |
| Number of persons registered for clinical study | 1700 |
| Number of persons with clinical manifestation | 255 |



**Figure 1**  Distribution of hand tube well water samples in different arsenic concentration area in Kasimpore, North 24 Parganas

In situ method, adopted in small experimental scale in the test site, is able to reduce the arsenic concentration of the ground water below acceptable WHO limit. However, more similar innovative methods need to be introduced to combat the menace of arsenic pollution.

### III.    Discussion:

Arsenic toxicity in the water in the Bengal Delta is one of the worst natural calamities in the modern time and affects millions of people. Other researchers have also come with similar results as shown below in Table 3. It seems to suggest that due to specific hydrological and biogeochemical conditions present in the Bengal delta, arsenic is releasing in the groundwater and getting into the human body through cooking and drinking water and food chain. Unless corrective actions are taken Arsenic will develop into severely genotoxic substance with high carcinogenic potential in humans.

**Table 3**

| Physical Parameters | Our case | Case 1 [34] | Case 2 [35] |
|---|---|---|---|
| Area in km2 | 5 | 148393 | 122 |
| Population density (No/km2) | 1000 | 808 | 1765 |
| Percentage of samples having arsenic above 10 μg/L | 76 | 93 | 78 |
| Percentage of samples having arsenic above 50 μg/L | 42 | 38 | 51 |
| Number of persons regsitered for clinical trial | 1700 | 18841 | 7221 |
| Percentage of population with clinical manifestation | 15 | 20 | 21 |

### IV.    Conclusion:

From the overall study in Kasimpore, one of the many arsenic affected blocks of West Bengal, it appears that the magnitude of the arsenic groundwater contamination in this block is severe. The presence of iron as well as the redox condition of the aquifer are very important. The process is very much dependant on the presence of iron which ultimately is forming the iron oxyhydroxide and doing the scavenging action of iron

removal. Another interesting observation is the dissolved oxygen (DO) level in the aquifer. DO level was found to be high throughout the experiments which further support the fact that there are not sufficient Fe (II) to get converted to Fe(III) and get precipitated. Hence the presence of less iron proved to be detrimental to the process. On the other hand, the reducing condition does not allow Manganese to function the way iron has done. Manganese or MnO2 require high redox potential to bring about the scavenging action. While oxygen rich water certainly reached the aquifer, the slope did not allow the whole effect to remain confined within the designated place. The study has further revealed that many people in this block, even if they are not showing arsenical skin lesions, might be sub clinically affected. The villagers reported that cancer rates are increasing among those suffering from severe arsenical skin lesions. Around 76% of the analyzed hand tubewells in Kasimpore block contain arsenic above 10μg/L. Therefore, it is of extreme urgency that they get a safe water supply immediately. It is reported that children are more susceptible to arsenic poisoning, which means a whole new generation is already at risk. Since at present there is almost no medicine for chronic arsenic poisoning, scientists all over the world should consider the issue a major challenge and determine a way to save the affected population.

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