Groundwater Arsenic Contamination Problems in Bihar: Causes, Issues and Challenges

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ABSTRACT: (9 pt)
Around forty percent of the district of Bihar is having arsenic in its groundwater. The causes of arsenic contamination are mostly through geogenic channel and human interference is not much conscientious for the problem. This paper tries to make an attempt to understand the groundwater arsenic contamination scenario, causes, issues and challenges in Bihar. The problems on social, economic and environmental issues are discussed in details. Almost 75-80 per cent of the rural populations rely on their drinking water from the groundwater sources. Excess use of arsenic in drinking water leads to several disease includes primary (black spots in the body, Keratosis) and secondary (white black spots in the body, Hyper-Keratosis, Non-pitting edema and liver and kidney disorders) health impacts in the long run. It has also tertiary health impacts causes gangrene of the distal organs, cancer of the skin, lungs and urinary bladder and kidney and liver failure. It has impacts on human health, food chain nuisance and socio-economic conditions hampers among the affected stakeholders. The agricultural activity is getting hampered due to decline in soil fertility and productivity. Social problems like depression, suicidal tendency and social ignorance are common. Young men and women with arsenicosis problems are not getting married. Contamination in drinking water hinders the social and economic activity to the effected person. The challenges are on the mitigation (at macro) and adaptation (micro as well as macro) activity. As the majority of the population resides in the arsenic prone belt are from low income and are not aware about the problems of the arsenic menace. Therefore both short term mitigation (hand pump treatment plan or sanitary dug well) and long term mitigation (alternative source of surface water) strategy is needed.

1. INTRODUCTION

Bihar along with few other states of India is facing an acute problem due to presence of arsenic menace in its groundwater. Groundwater is the main source of drinking water and it constitutes more than 80 per cent of drinking water source in rural Bihar. The other sources of drinking water are from surface water, dug well, pond and from natural sources (lakes, rivers etc.). Few percentages of rural households are using drinking water from protected dug wells. The groundwater sources were considered safe for drinking water but over the past few years, they have reported contamination and pollution problems in its root due to rapid urbanisation, industrialisation and excess extraction of groundwater for irrigation purpose.

Around forty percent districts of Bihar has reported arsenic contamination problem in its groundwater. This comprises of more than 67 blocks from 15 districts and covering more than 1500 habitations across the state where arsenic contamination in groundwater exceeds the BIS limits for safe drinking water of 50 particle per billion (ppb) and more. If we consider the WHO limits of 10 ppb, the coverage area will be much more and the population which is facing the danger of arsenic hazard will be thrice of the Bureau of Indian Standard (BIS) limit. It has been estimated that more than 13.85 million people could be under the threat of contamination level of above 10 ppb/l, out of which more than 6.96 million people could be above 50 ppb/l, against the total population of these area is around 50 million (MoWR, 2010). The actual problem of arsenic menace among the population will be increasing at an alarming rate by every new survey done by Central Ground Water Board (CGWB) and Public Health Engineering Department (PHED), Govt. of Bihar.

Arsenic is a shiny metalloid that dissolves in water. It is a natural mineral, present in the soil and aquifers, and the concentrations above the safe level in drinking water may cause significant health risks. Most arsenic enters water supplies either from natural deposits in the earth or from industrial and agricultural pollution. Arsenic is a natural element of the earth's crust. Although surface water are mostly considered safe for drinking water but groundwater sources are arsenic contaminated in the range of 40 – 140 metre. It is used in industry and agriculture, and for other purposes. It is also a by-product of copper smelting, mining and coal burning.

Access to safe water supply is one of the most important factors of health and socio–economic development (Cvjetanovic, 1986). More than 150 million people are affected worldwide by arsenic contamination in 70 countries, out of which 50 million people in Bangladesh and 30 million people in India are at risk (Ravenscroft et al., 2005). Arsenic is toxic in nature and the excess quantity of its use in drinking water leads to several health hazards. Drinking arsenic contaminated water over a long period results in various health effects including skin problems such as colour changes on the skin, and hard patches on the palms and soles of the feet (WHO, 2010). It also leads to skin cancer, cancer of the bladders, kidney and lung, and diseases of the blood vessels of the legs and feet, and also possibly diabetes, high blood pressure and reproductive disorders (*ibid*).

Given the background, this paper has attempted to understand the issues and challenges posed by arsenic groundwater contamination problems and its menace of the affected population in Bihar. The paper is divided into four sections. Followed by brief introduction and background problem, the second section is on water pollution and arsenic scenario. In this section, water pollution and arsenic scenario have been discussed in details. Third section deals with issues and challenges faced by arsenic in drinking water. This section also explains about the possible solutions for the emerging challenges. The fourth section comprises of concluding remarks.

2. WATER POLLUTION AND ARSENIC SCENARIO

Air and water pollution are major environmental problems currently exist in India along with depletion of non-renewable resources and degradation of renewable resources (Sankar, 2000). Resources are economic goods while pollutants, the degrader of resources are economic bads. Pollutants are the reverse of the resources (Dasgupta, 2010) and pollution is thus the reverse of conservation (Dasgupta, 1993 and 2007). Pollution can be thought of as a pure public bad and hence pollution reduction as a public good (Baliga and Maskin, 2005). Pollution is treated as negative externalities in economics literature (Pigou, 1920, Sankar, 2005). When certain actions of producers or consumers have unintended effects on other producers or consumers externality arises. Externality is of two kinds positive and negative. Externalities may be global public bads (emissions of greenhouse gases, climate change, depletion of ozone layer, loss of bio-diversity and extinction of endangered species and other are some of the examples of global public bads) which have global effect and local public bads (problem of groundwater or surface water in a region, land degradation, air and vehicular pollutions and others are some of the examples of the local public bads) which have local or regional effect. Climate change problem aggravate the availability of water in the country as it threatens the water cycle. As the population increases the demand for agriculture also grows and the demand of water thus increase. Table 1 provides information on projected water demand in India by different uses.

Table1. Projected water demand in India (by different uses)

SI No.	Sector	Water Demand in Km^3 (BCM)								
		Standing Sub-committee of MoWR			NCIWRD					
		2010	2025	2050	2010		2025		2050	
					Low	High	Low	High	Low	High
1	Irrigation	688	910	1072	543	557	561	611	628	807
2	Drinking Water	56	73	102	42	43	55	62	90	111
3	Industry	12	23	63	37	37	67	67	81	81
4	Energy	5	15	130	18	19	31	33	63	70
5	Other	52	72	80	54	54	70	70	111	111
Total		813	1093	1447	694	710	784	843	973	1180

Source: MoWR 2010

2.1 Water Pollution

Water pollution is major concern in India and particular in Bihar. With around 17 percent of the world's population but only 4 percent of its usable freshwater, India has a scarcity of water. World oceans cover about 3/4th of earth's surface. But fresh water constitutes small proportions. About 2.7 percent of the total water available on the earth is fresh water, of which about 75.2 percent lies frozen in Polar Regions and another 22.6 percent is present as groundwater (Ministry of Water Resources India (MoWR), 2007; and United Nations Report (UN), 2005). A small proportion (about 2 percent) of total fresh water is available in lakes, rivers, atmosphere, moisture, soil and vegetation.

Water resources of a country constitute one of its most significant economic assets and the different forms of water resource development differ for various uses, fluctuate from country to country depending on its climatic, physiographic, and socio-economic conditions and development (Jain, 1977). India is rich in both surface water and groundwater resources. India has total annual replenishable groundwater resources of 433 billion cubic meters (BCM), net annual groundwater availability of 399 BCM, annual ground water draft for irrigation, domestic and industry is around 233 BCM, and stage of groundwater development is around 58 percent. Annual precipitation (includes snowfall) in India is 4000 cubic kilometers while average annual availability of water resources is around 1869 cubic kilometers. Per capita water availability is 1820 cubic meters according to 2001 ministry of water resources sources. Estimated utilized water resources is 1122 cubic kilometers in which surface water resources share is 690 cubic kilometers and groundwater resource share is 431 cubic kilometers.

Bihar is rich in groundwater resources. In Bihar, annual replenishable groundwater resources, net annual groundwater availability and annual groundwater draft are 29, 27.42, and 10.77 BCM. The stage of groundwater development in Bihar is 39 percent and the annual rainfalls (in mm) are 1232. The per capita water availability is decreasing in both Bihar and India. In 2001, per capita availability of water (in cu. m) was 1950 and 1816 for Bihar and India. It has further decline to 1545 and 1200 (in cu. M) in 2011. The decline in availability of groundwater in Bihar is due to the uncontrolled population growth, excess dependence on groundwater (85 percent), over extraction of groundwater for irrigation, uncontrolled deforestation. This leads to overall water quality problems. But water is becoming increasingly scarce over the years. Uncontrolled growth of population, expansion of irrigation channels and developmental activity are responsible for the decline in water availability problems. It also leads to problems in water quality which affects the health and other problems. Different groundwater contamination problems in Bihar are given in table 2.

Table2. Different Groundwater Contamination in Bihar

Contamination	Permissible Limit	Health Effects	Location and status
1. Arsenic	10 ppb by WHO 50 ppb by BIS	> 50 ppb in drinking water is toxic and have human health hazard.	15 districts and 57 blocks of Bihar are highly affected by arsenic in their groundwater. Arsenic is toxic in nature and excess use of it in drinking water for long run causes different kind of cancer. It also hampers the socio-economic conditions of the affected persons. The highest concentration of contamination was found 1810 and 1630 ppb at Maner and Shahpur block of Patna and Bhojpur district.
2. Fluoride	Upto 1.5 mg/l in drinking water < 1 mg/l is beneficial	> 1.5 mg/l is harmful and resulted in staining of tooth enamel.	14 blocks of 9 districts and highest concentration was at Navinagar (2.85 mg/l) of Jamui block. Higher level of fluoride (5-10 mg/l) causes stiffness of the back and difficulty in performing natural movement.
3. Iron	Upto 1 mg/l in drinking water	> 1.5 mg/l is harmful	Iron is common water contaminant found in Bihar. 31 blocks from 20 districts is having Iron in groundwater. The highest concentration of Iron was found at Jeradai (14 mg/l) of Mairwa block from Siwan district.
4. Nitrate	Upto 45 mg/l in drinking water	>45 mg/l in drinking water is harmful for infants.	It is difficult to identify natural and man-made sources of nitrogen in ground water. It generally originates from non-point sources and is the most common contaminant of groundwater.15 blocks from 9 districts is having Iron in Bihar. The highest concentration was found at Mokama (228 mg/l) of Fatuah block from Patna.

Source: Author's own compilation from various sources (MoWR, 2010a and 2010b)

2.1.1 Arsenic Contamination – Causes and Sources

Arsenic is found in the natural environment in plenty in the earth's crust and in small magnitudes in rock, soil, water and air and is always present as compounds with oxygen, chlorine, sulphur, carbon and hydrogen on one hand, and with lead, gold and iron on the other (MoWR, 2010b). It can exist in both organic and inorganic form but inorganic arsenic is more toxic than organic arsenic. Inorganic arsenic compounds are known to be more human carcinogens. Arsenic in element form is insoluble in water and soluble in oxidized form. Countries including Argentina, Bangladesh, Chile, Ghana, Mexico, Mongolia, India, Taiwan, Vietnam, and United States are exposed to arsenic problems because the sources of arsenic are primarily natural rather than anthropogenic or geothermal. Inorganic arsenic of geological origin has been recognised as the main form of arsenic in groundwater.

Sparks (2005) suggested three source of arsenic in soil and aquatic ecosystem. It consists of Biogenic, Geogenic and anthropogenic sources of arsenic. By and large geogenic sources are responsible for arsenic contamination but anthropogenic activities also cause contamination. The anthropogenic sources of arsenic occur due to human activities. The main source of anthropogenic can be further classified in three categories viz. agricultural, industrial and others. Agricultural sources of arsenic can be from pesticides, herbicides, seed treatment, cattle deep and fertilizer mainly, while industrial sources are from timber treatment, tannery, electro plastic, and paints and chemicals. Other anthropogenic sources are from sewage and smelting.

2.1.2 Arsenic Scenario

Arsenic is a heavy metal and regarded as a toxic element. Excess of arsenic in drinking water over long run is considered as a human health hazard and leads to different diseases. In extreme cases it leads to an end of human life. Seven states of India have reported arsenic contamination in groundwater and it is increasing at increasing rate (MoEF, 2009). Out of reported seven states, Bihar and West Bengal have severe impact of the livelihoods of the stakeholders due to arsenic menace.

More than 70 countries are globally affected directly or indirectly with arsenic contamination in drinking water which affects more than 150 million people across the globe. Around middle of the 20th century, arsenic poisoning surfaced in those areas where people ingested arsenic contaminated water. The major affected countries from arsenic poisoning were Argentina, Chile, Mexico, Taiwan, and some part of the United States. In global arsenic contamination scenario, 38 countries are affected more severely at present. At the last quarter of 20th century three Asian countries (Bangladesh, China, and India) came to lime light due to their suffering from groundwater arsenic contamination. The major source of arsenic contamination was contaminated hand tube-wells. As of 2010 September, 13 Asian countries are arsenic affected and the level of arsenic contamination in Asian countries is more severe than the rest of the world. Bangladesh is the worst affected country, as 60 of its total 64 districts have arsenic groundwater contamination above World Health Organization (WHO), 2001 guidelines of 10mg/l for safe drinking in water. In India, flood plains of all the states in Ganga and Brahmaputra rivers are arsenic affected.

The first case of arsenic in India was reported in 1976 from Chandigarh, where some patients were suffering from noncirrhotic portal hypertension (NCPH) and later it was found that the water used by patients who suffered from NCPH came from arsenic contaminated tube wells (MoWR, 2010b). In 1982 a patient from North - 24 Parganas district of West Bengal, whose skin lesions were not like the usual skin diseases and later similar problem finds to many patient from the same village suffered from such problems in soles of their feet, palms of their hands, ulcer in hands and bodies and found that due to the excess availability of arsenic in tube wells in drinking water (MoWR, 2010a). Soon after the incident four districts of West Bengal (North 24 Parganas, South 24 Parganas, Nadia, and Murshidabad) were found on arsenic menace in ground water. In 1983, 33 villages of 4 districts were identified, having arsenic contamination. By the end of 2004, 3200 villages of 85 blocks from 9 districts were identified having arsenic contaminated water and by the end of 2008, more than 3417 villages of 111 blocks from 9 districts have reported arsenic contaminated groundwater (MoWR, 2010b).

In 2002, two villages (Barisban and Semaria Ojhapatti) from the Bhojpur district of Bihar in the middle Ganga plain reported excess of arsenic contamination exceeding 50 mg/l (Chakraborty et al., 2003). As of 2009, out of 38 districts of Bihar, 57 blocks from 15 districts having total population more than 10 million have been reported to have arsenic groundwater contamination above 50 mg/l (MoWR, 2010a and 2010b, MoEF, 2009). Due to the excess arsenic contaminated drinking water, 18 babies were born blind in the Bhojpur district. The demographic survey done by many organizations mainly in Bihar and West Bengal estimated that more than 13.85 million people could be under the threat of contamination level above 10 mg/l, in which more than 6.96 million people could be above 50 mg/l, against the total population of those areas of the order of 50 million (MoWR, 2010b). Live-stock in large number has also been exposed to arsenic contaminated groundwater. In the arsenic affected areas, arsenic contaminated groundwater is also used for agricultural irrigation. This leads to the possibility of arsenic exposure through food chain not only in contaminated areas but also in areas with no contamination due to open market sale of food products.

Out of seven states, two states of India namely Bihar and West Bengal are worst affected by arsenic contamination in their groundwater. Altogether more than 40 percent of the people from Bihar and West Bengal are affected by arsenic contamination in groundwater which causes serious threats to the people of the state in health and other hazards which threats to the socio - economic status of the affected people. Table 3 presents the arsenic contamination problem in Bihar.

Table 3. Occurrence of high Arsenic in Groundwater in Bihar (> 50 ppb/l)

Serial No.	District Name	Total Block	Total affected Blocks	Total Affected Habitations
1.	Begusarai	18	4	84
2.	Bhagalpur	16	4	159
3.	Bhojpur	14	4	31
4.	Buxar	11	4	385
5.	Darbhanga	18	1	5
6.	Katihar	16	5	26
7.	Khagaria	7	4	246
8.	Lakhisarai	7	3	204
9.	Munger	9	4	118
10.	Patna	23	4	65
11.	Samastipur	20	4	154
12.	Saran	20	4	37
13.	Vaishali	16	5	76
	Total	**195**	**50**	**1,590**

Source: PHED, Govt. of Bihar (2012)

3. ISSUES AND CHALLENGES

Scarcity of safe drinking water in the rural areas of Bihar acquainted with social and economic issues. It also threats the environment as well as major health problems. Contamination in drinking water hinders the social and economic activity to the affected person.

The evidence on the adverse impacts of water pollution in general and on human health in particular is well known. High concentration of contamination in drinking water – arsenic, fluoride, iron, nitrate and lead- contribute to both human mortality and morbidity. Prolonged exposure to water contamination could lead to different disease. Epidemiological studies show that arsenic in drinking water cause cancer (Canter 1997, Chakraborty and Saha, 1987). Arsenic in drinking water over long run can cause the problems in the reproductive system, birth defects and harm the central and peripheral nervous system (Canter, 1997) and excess acquaintance of arsenic during pregnancy can adversely affected reproductive endpoints (Mukherjee, 2006). The dose-response relation between low arsenic concentrations in drinking water and arsenic-induced skin Keratosis and hyper pigmentation is well characterized (Haque et al., 2003). The arsenic related skin disease may be associated with increased risks of skin, bladder and lung cancer (NRC, 1999). Without skin lesion also cancer risks can prevail (*ibid*). Such health problem has involved economic, social and environmental costs to the affected stakeholders. Arsenic in drinking water hinders the social as well as economic costs to the society in general and affected households in particular. Health problems caused by pollution have economic costs arising from the expenses incurred in treating the disease and loss of productivity (Bates, 1990, Ostro, 1994, Banerjee, 2001, Adhikari, 2012). Skin lesions poses an important public health concern in Bangladesh and West Bengal, India as advanced forms of Keratosis are painful and if untreated can lead to social isolation among the affected villages (Haque et al., 2003, Haque and Khan, 2011).

While most of the arsenic studies are concentrated on arsenic are epidemiological studies. In epidemiological studies it has been tried to link exposure of arsenic in drinking water over period of time causes acute illness. The studies are cross-section in nature and focused more on current exposure to the illness. The long term (5 to 10 years) exposure of arsenic in drinking water forms the basis of skin lesions (Keratosis, Melanosis), hyper pigmentation, and increased risks of lung, bladder and skin cancers, birth defects and peripheral nervous system.

Arsenic related exposure hinders the social and economic cost of the affected person. There are very few studies available which has focused on both social and economic factors and tried to estimate the socio-economic cost involved to the household due to exposure of arsenic in drinking water. Arsenic in drinking water causes different types of cancer. National Academy of Sciences (NAS) 1999 suggested that arsenic level in tap water and its total cancer risk. Table 4 presents Arsenic in Drinking Water and Cancer.

Table 4. Arsenic in Drinking Water and Cancer

Arsenic Level in Tap Water (in parts per billion, or ppb)	Approximate Total Cancer Risk (assuming 2 liters consumed per day)
0.5 ppb	1 in 10,000
1 ppb	1 in 5,000
3 ppb	1 in 1,667
4 ppb	1 in 1,250
5 ppb	1 in 1,000
10 ppb	1 in 500
20 ppb	1 in 250
25 ppb	1 in 200
50 ppb	1 in 100

Source: National Academy of Sciences (1999)

The arsenic problem has a major effect on the socio - economic structure. The socio – economic problems can be mainly categorised into three classes as agricultural problem, health problem and other problems. Excess presence of contaminated water leads to decrease in agricultural productivity, soil fertility, and also enters into the food chain which creates health problems. Brammer (2008) suggested that in India, Nepal and Bangladesh arsenic contaminated water used for irrigation enter into the food chain. All these three problems lead to both social and economic problems. Skin lesions, bladder and cancer, and mortality are few of the health problems. Social ignorance, depression and suicidal tendency are among few social problems.

Arsenic contamination has widespread social problems among the affected households. Social problems are linked with the health and the economic problems. Arsenic related diseases are not spreadable disease. It is common myth among the households in rural areas that it is a spreadable disease. The possible solution is to initiate awareness programme by the government at the community or grassroots level.

Arsenic groundwater contamination has severe economic effect on the people residing in the areas where the menace is found. Study found that poor people are more prone to suffer from such problem. There is dearth of studies on economic aspects of arsenic problems. The chronic effects of inorganic arsenic exposure via drinking water include skin lesions, such as hyper pigmentation and black foot disease, and respiratory symptoms, such as cough and bronchitis. Besides, there is sufficient evidence to link bladder and lung cancers with ingestion of inorganic arsenic (NRC Report, 2006).

Arsenic contaminated groundwater is used for agricultural irrigation resulting in excessive amount of available arsenic in the crops in that area. It has been reported that second to the ingestion of arsenic, after the direct consumption as drinking arsenic contaminated water, is through food chain, particularly use of contaminated rice followed by vegetables. This eventually indicates that the effects of this occurrence are far-reaching; sooner we search sustainable solutions to resolve the problems, lesser be its future environmental, health, socio-economic and socio-cultural hazards (MoWR, 2010b). The fertilizers and pesticides used for agricultural purpose also cause arsenic contamination. Rice and vegetables have more effects on arsenic contaminated water. Brammer (2008) in his study suggested that arsenic-polluted water used for agriculture irrigation is a health hazard for the people eating food from the crops irrigated in the areas of India, Bangladesh and Nepal in recent times. Arsenic contaminated water used for irrigation can adversely affect the soil quality and hence reduce food production. Arsenic contaminated groundwater used for irrigation in the countries of south and south-east Asia is adding arsenic to soils and rice. This poses a serious risk to sustainable agricultural production and also the livelihoods and health of the affected population of those countries (Brammer, 2009). The possible mitigation strategy or measures should be needed. Two possible options can be possible. The first is to provide the alternative irrigation sources and the second will be removing the contaminated soil by using the appropriate technology.

4. CONCLUDING REMARKS

Bihar is one of the least developing states of India both in terms of per capita income and human development index. In the last few decades pollution of water level has increased due to excess exploitation of groundwater resources for irrigation and drinking purposes, rapid increase in industrialisation and urbanisation. Groundwater level is increasingly falling in many parts due to excess drawls leading to contamination problems with nitrate, fluoride, arsenic and other chemicals and also contributes to contaminating potable water sources.

Accesses to safe and clean drinking water along with sanitation are basic human needs. They are fundamentally linked to the health and wellbeing of the people. The majority of the people are facing arsenic in their drinking water is from poor socio-economic background. They are either not aware or if aware are forced to take drinking from same source due to lack of alternative sources of water. As Prime minister of India Dr. Manmohan Singh rightly said in his 2012 IWW speech that "*With around 17% of the world's population but only 4% of its usable freshwater, India has a scarcity of water. Rapid economic growth and urbanisation are widening the demand supply gap. Climate change could further aggravate the availability of water in the country as it threatens the water cycle. Our water bodies are getting increasingly polluted by untreated industrial effluents and sewage. Groundwater levels are falling in many parts due to excess drawls leading to contamination with fluoride, arsenic and other chemicals. The practice of open defecation, which regrettably is all too widespread, contributes to contaminating potable water sources*". If we cannot be aware and take action then the condition of contamination will be worse than Bangladesh which will certainly affect sustainable health of the stakeholders in all aspects of life.

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