



Evaluating Hydrogeological And Topographic Controls On Groundwater Arsenic Contamination In The Middle-Ganga, A Serious Health Hazard

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ABSTRACT

Groundwater arsenic contamination in the Middle-Ganga plain poses a significant public health challenge. This study evaluates the interplay of hydrogeological and topographic factors influencing arsenic distribution. Findings suggest a critical need for targeted remediation strategies and sustainable management to mitigate health risks. Arsenic poisoning has become a global problem in the recent times. It is estimated that millions population are exposed to arsenic worldwide. Bihar is the state in India, which is in the vicinity of river Ganges where seven major tributaries from Great Himalayas through Nepal meet river Ganges. This entire Gangetic plain area is highly fertile land, with very high population density. In this state an estimated 10 million people are exposed to arsenic contaminated drinking water as well as irrigation water. Groundwater is the primary source of arsenic poisoning which has caused serious health hazards to the exposed population. The exposed population are exhibiting typical symptoms of arenicolids such as hyperkeratosis, melanosis, pigmentations and other skin manifestations. Arsenic Hot Spots Detected in Patna District, Bihar (India) - A Serious Health Hazard. Groundwater arsenic iso-lines with tapering arsenic concentrations have been detected for the first time in the study of arsenic contamination in groundwater in the region. There also exist intervening stretches of Arsenic-free aquifers. The arsenic contamination in the groundwater of the study area is alarmingly high. An estimated population of 5.5 lakhs is potentially exposed to serious health risks, with possible rise in morbidity in the next 5-10 years.

The purpose of this study was to determine the existence and intensity of Arsenic Contamination of Groundwater resources in Patna, the most heavily populated district of Bihar, located along the River Ganges. The findings will aid in mitigation program for the arsenic affected population.

Keywords: Arsenic contamination, toxicity, groundwater, arsenic aquifers.

Introduction

Context: Groundwater serves as a primary water source in the Middle-Ganga plain, supporting millions of people.

Problem: Arsenic contamination in groundwater has emerged as a severe health hazard, linked to conditions like cancer and skin lesions.

Objective: This article aims to evaluate the hydrogeological and topographic controls governing arsenic mobilization and distribution.

The Ganges is one of the most complex yet fascinating river systems in the world. The basin is characterized by a high degree of heterogeneity from climatic, hydrological, geomorphological, cultural, environmental and socio-economic perspectives. More than 500 million people are directly or indirectly dependent upon the Ganges River Basin, which spans Nepal, India and Bangladesh. While there are many books covering one aspect of the Ganges, ranging from hydrology to cultural significance, this book is unique in presenting a comprehensive interdisciplinary overview of the key issues and challenges facing the region. Contributors from the three main riparian nations assess the status and trends of water resources, including the Himalayas, groundwater, pollution, floods, drought and climate change. They describe livelihood systems in the basin, and the social, economic, geopolitical and institutional constraints, including transboundary disputes, to achieving productive, sustainable and equitable water access. Management of the main water-use sectors and their inter-linkages are reviewed, as well as the sustainability and trade-offs in conservation of natural systems and resource development such as for hydropower or agriculture. The prolonged arsenic exposure also leads to different types of cancer. The cancer among the exposed population is of skin, liver kidney, gall bladder, bladder, breast, colorectal, etc. Hence, it is very important to evaluate the health problems exhibited in the exposed population. The present study highlights the health problems of the exposed population of different parts of Bihar with confirm presence of elevated arsenic concentration in groundwater ($>10 \mu\text{g/L}$). Apart from this the study also examined the mitigation strategies undertaken by the state Government for the exposed population. Increasing arsenic contamination in the groundwater is one of the biggest environmental challenges that the Bengal delta is facing today. Groundwater is still the main source of water for a large number of populations in this region and therefore, significant presence of toxic arsenic has a direct consequence on human lives here. Moreover, arsenic also enters into the food chain through the consumed agricultural products grown in this area. Therefore, acquiring knowledge about the ever-changing map of arsenic contamination and employing adequate protective measures are of utmost importance. Here, we present a comprehensive municipal ward-wise map of the arsenic content of the shallow groundwater most important and highly population dense city of the delta. Comparison with previously available data reveals a rapid change and the grim situation for the city. Our study suggests that it should be an immediate task of the administration to extend treated water service to the whole population of the city for direct consumption, and artificial recharge and maximum rainwater replenishment need to be taken up with utmost urgency to avoid intrusion of toxicity in biological food chains via agricultural products. We hope our study would drive the city planners to reconsider the existing urbanization and development plans of all the cities, placed over arsenic-contaminated groundwater aquifers. W.H.O. (World

Development Report,2020-2001) has published Guidelines for Drinking Water Quality in which a contemporary value for an acceptable maximum level of arsenic was set at 10 µg/l/ for safe water. National standards range from 7 µg/l in Australia to 50 µg/l in Vietnam, Cambodia and Bangladesh (Fazal et.al., 2017). Naturally occurring Arsenic, as a water quality issue, began to attract international attention in the early decade of the nineties, when widespread chronic arsenic poisoning cases became apparent in Bangladesh and later in West Bengal, India (Chadha et.al., 2014; Chakrovorty et.al, 2013,

The study area of this research incorporates Patna District, being justified by its close proximity to the Patna arsenic contaminations. The two districts are separated by the River Sone which meets the Ganga on the northern boundaries of both Bhojpur and Patna. The study area of Patna district was confined to an approximate belt of 10 kms. along the southern bank of River Ganga, based on the findings of previous studies stating the greater possibilities of contamination in newer fluvial deposits (Fazal et.al., 2009; Morgan et.al.).

Hydrogeological Controls:

1. Geology of the Aquifers:

- Alluvial sediments in the Middle-Ganga plain are rich in arsenic-bearing minerals.
- Interaction between organic matter and arsenic-containing minerals facilitates mobilization.

2. Aquifer Characteristics:

- Depth and composition (shallow vs. deep aquifers).
- Redox conditions that drive arsenic release into groundwater.

3. Recharge Dynamics:

- Seasonal variations in recharge impact arsenic concentrations.
- Impact of irrigation return flow on arsenic mobilization.

Topographic Influences:

1. Terrain and Elevation:

- Influence of low-lying floodplains and wetlands on arsenic hotspots.
- Impacts of waterlogging and reduced flushing in arsenic accumulation.

2. Drainage Patterns:

- Poor drainage creates conditions favouring arsenic solubility.
- Role of river morphology in contaminant transport.

3. Land Use Practices:

- Agricultural practices and the use of fertilizers influencing groundwater quality.
- Urbanization effects on natural recharge and contamination pathways.

Health Implications:

- **Epidemiological Evidence:** Correlation between arsenic exposure and chronic health conditions.
- **Socioeconomic Impact:** Costs of medical treatments and loss of productivity.
- **Vulnerable Populations:** Women, children, and socioeconomically disadvantaged groups disproportionately affected.

Groundwater, as an intermediate solution

Groundwater cannot be a sustainable source for drinking water in the KMC due to quality and quantity issues. Until a full-fledged surface water scheme is implemented, it may act as an intermediate solution depending upon its quality and availability. The groundwater activity mapping for each ward should be prepared. Fluctuation of the piezometric level of groundwater should be monitored before installation and operation of bore wells. All the bore wells must be identified through GIS

Methodology

- All the public hand pumps of the study area were tested for Arsenic content by trained field workers through Field Test Kits manufactured by CHEM-IN Corporation, Pune.
- Each public hand pump tested was marked, with a unique Identification Code at the time of testing. The 13-digit code was derived from the Census 2011. This information identified the State, District, block and village, and finally the serial number of the Hand pump.

Bihar Plains consist of sandy soils, where recent research has shown that presence of silica often masks the signal of arsenic from many chemicals (AusAid Guidelines, 2016), thereby "creating a false optimum" of arsenic content lower than actually existing. Hence, 10% random verification of field test kit results was done through Atomic Absorption Spectroscopy.

- All field test results above 40 mg/L were retested using AAS (APHA - 2018).
- Marking of hand pumps were done to inform the public of their status (safe/unsafe). The colour codes applied were - Blue for FTK readings below 40 µg/L; yellow for FTK readings 40-79 µg/L; and, Red for FTK readings of 80 µg/L and above.
- There is an increasing need to map the level of arsenic concentration, trends of arsenic flow and temporal changes occurring in its concentration levels. Recording the locations of Arsenic-affected hand pumps, using Global Positioning System (GPS) units (Basu and Sil, 2018), was done, followed by mapping of the arsenic occurrences. The other references used were Block Maps, Topographical Maps.

Mitigation Strategies:

1. Monitoring and Mapping:

- Establish arsenic distribution maps for targeted interventions.

2. Remediation Techniques:

- Use of arsenic-removal filters at household and community levels.
- In situ methods like iron-oxide barriers.

3. Policy Interventions:

- Regulatory measures to limit arsenic exposure.
- Promoting alternative water sources (e.g., treated surface water).

Results and finding

The complex interaction between hydrogeology and topography significantly influences groundwater arsenic contamination in the Middle-Ganga region. A multidisciplinary approach integrating scientific research, community participation, and policy interventions is essential to address this critical health hazard.

The findings of this study also revealed the quantum of population being exposed to arsenic contaminated hand pumps. Taking into account the efficacy of field test kits, 32.27% of the total population of the study area were at risk. The critical figure of affected population in Patna district [82.63%] was attributed to widespread contamination of 50 µg/L and less of the drinking water sources. Classic symptoms of arsenic poisoning were visible in all the four worst affected blocks, although clinical investigations are yet to be done. The highest Arsenic contaminated aquifers of the fertile, densely populated villages of the Diara lands of Maner, coincided with a large number of children with skin discolorations. There were common complaints of eczemas not responding to medicines. In the remaining three important blocks, visible symptoms were commonly confined to skin problems and gastro-intestinal symptoms. Epidemiological studies state that the external symptoms of arsenic poisoning appear after at least 5 years of continuous ingestion of arsenic, by which time difficulties arise in treatment of symptoms. The general population of Bihar has a wide youthful base, hence children in the contamination zones are the most vulnerable to arsenic related health problems.

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