J. Chemtracks 27 (1&2) 253-260, 2025

Abstracted / Indexed in
CAS
A division of the American Chemical Society
Chemical Abstract U.S.A.

ISSN 0973-239X
CODEN:JCOHF7
IMPACT FACTOR : 7.866

Groundwater Quality Assessment of Araria District, Bihar : A Review

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Manuscript received online 10 September 2025, accepted on 20 October 2025

Abstract : Groundwater serves as a lifeline in Araria district, Bihar, sustaining both drinking water needs and agricultural productivity. Despite this critical dependency, comprehensive data on groundwater quality across the district remains fragmented. This review consolidates available literature, government reports, and regional case studies to provide a detailed assessment of groundwater quality in Araria. Key hydro-chemical concerns include the probable presence of arsenic, iron, and fluoride contaminants commonly found in the Indo-Gangetic basin. The paper discusses aquifer characteristics, contamination risks, potential health impacts, and recommendations for groundwater monitoring and sustainable use. The review emphasizes the urgent need for systematic sampling, geospatial analysis, and localized treatment interventions to safeguard water quality in this under-researched district.

(Keywords : Araria, Groundwater quality, Arsenic, Fluoride, Iron, Aquifer mapping, Water contamination).

Introduction

Water is a marvelous substance-flowing, rippling, swirling around obstacles in its path, seeping, dripping, trickling, constantly moving from sea to land and back again. Water can be clear, crystalline, icy green in a mountain stream, or black and opaque in a cypress swamp. Water bugs skitter across the surface of a quiet lake; a stream cascades down a stairstep ledge of rock; waves roll endlessly up a sand beach, crash in a welter of foam, and recede. Rain falls in a gentle mist, refreshing plants and animals. A violent thunderstorm floods a meadow, washing away stream banks. Water is a most beautiful and precious resource [1].

Water is nature's most wonderful, abundant and useful compound of the many essential elements for the existence of human beings, animals and plants (viz, air, water, food, shelter, etc.), water is rated to be of the greatest importance. It is the major component of all living things, constituting 70% of every adult human body and from 50% to 95% of different plants and animals. Water enters our bodies through the liquids that we drink and the foods that we eat; it leaves the body in the form of urine, feces, sweat and exhaled air. Human can survive only a few days without water. It is a crucial compound for the survival of all life forms. The importance of water as essential constituent of our body is well known since ancient time. It is well known fact that 70% of the earth's surface is covered by water. Water is the main controlling factor of atmosphere, trade, civilization, culture, agriculture and remains active all the time and continues its journey through "hydrological cycle" from one part of the biosphere and atmosphere to another and keeps on changing its form among solid, liquid and gas.

The Composition of Natural Pure Water :

The chemical formula of water is H_2O but the actual natural water[2] is a mixture of the following:

(i)	H_2O^{17}	(ii)	H_2O^{18}	(iii)	HDO^{16}
(iv)	H_2O^{16}	(v)	HDO^{17}	(vi)	HDO^{18}
(vii)	D_2O^{18}	(viii)	D_2O^{17}	(ix)	D_2O^{16}

where $_1H^1$, $_1D^2$, $_1T^3$ and $_8O^{16}$, $_8O^{17}$, $_8O^{18}$ are the isomers of hydrogen and oxygen respectively.

These nine combinations are due to the isotopes of hydrogen and oxygen. Since the proportions of these nine constituent of natural water varies place to place hence the property of water also varies from place to place.

Physical Properties of Water : Pure water is a colourless and tasteless and odourless liquid. It has freezing point 0.001°C at 760 mm of Hg and boiling point 100°C.The dielectric constant and electric conductivity at 20°C are 78.39 $C^2/N.\ m^2$ and $5.7x10^{-8}$ $ohm^{-1}cm^{-1}$. If pure water is heated from 0°C to 4°C its volume does not increase but contracts and attains its maximum density at 4°C. If water is allowed to freeze it expands instead of being contracted and hence its density decreases and this is the reason that ice slabs floats on the surface of water Bodies[2]. The physical properties of water[2] are given in Table -1.

Table -1
Physical Properties of Water

Property	Value
Molecular mass	18.0151 $gmol^{-1}$
Melting point	273.0 K
Boiling point	373.0 K
Enthalpy of formation	-285.9 $kJmol^{-1}$
Enthalpy of vaporization	40.66 $kJmol^{-1}$ at 373K
Enthalpy of fusion	6.01 kJ mol^{-1}
Temp. of max density	276.98 K
Density	1.0000 gcm^{-3} at 298 K
Viscosity	0.8903 centipoises
Dielectric constant	78.39 C^2 / N. m^2
Electrical conductivity	$5.7x10^{-8}$ ohm^{-1} cm^{-1} at 293K

The unusual properties of water in the condensed phase (liquid and solid states) are due to the presence of extensive hydrogen bonding between water molecules. This leads to high freezing point, high boiling point, high heat of vaporization and high heat of fusion in comparison to H_2S and H_2 Se. In comparison to other liquids, water has a higher specific heat, thermal conductivity, surface tension, dipole moment and dielectric constant, etc. These properties allow water to play a key role[3] in the biosphere.

Importance of water for the Biosphere: Without water life as it exists on our planet is impossible. The importance of water[4] in sustaining a healthy biosphere on our planted can be summed up as follows:

* Water is the very medium in which all biochemical reactions within a living organism and a large number of chemical reactions involving components of rocks, soil and pollutants of environment occur. It is the availability of water which determines the nature, composition and abundance of terrestrial life. Regions with very low rainfall become deserts. Lush green vegetation develops where water is in abundance.
* Due to its high specific heat, changes in its temperature need large amount of heat energy or its withdrawal as compared to other objects. This causes temperature differences between land and sea when heated by solar radiation and an active air circulation is maintained. The air circulation in turn determines precipitation pattern and climatic conditions of locality.
* A high latent heat of vaporization causes a large amount of heat energy to be used up in evaporation of water. The solar heat could have, otherwise, raised global temperature significantly.
* Water vapours effectively absorb long wavelength radiations as carbon dioxide does. It acts like a greenhouse gas and plays an important role in regulating the temperature of earth's crust.
* The unique property of expansion, when cooled below 4°C causes water to freeze from top downwards as aquatic bodies lose or gain most of their heat energy from the

surface in contact with air above. Aquatic life stays safe under the ice-sheet.

* It is because of extraordinary high surface tension that a considerable amount of water is retained in the soil due to capillary action. It is on this moisture that green plants thrive during dry periods.
* Water is an efficient means of transfer and transport of the material dissolved or suspended in it. Low lying regions of the world, river basins, land along sea coasts are, therefore, much more productive than upland areas. Water transports dissolved materials, silt, debris, nutrients and pollutants etc. from upland areas to low lying regions. Nearly 90% of world population is, therefore, concentrated in these areas.
* Water plays an important role in weathering of all types of rocks and the formation of soil.
* Water also plays an important role in reducing the atmospheric burden of particulates and gaseous pollutants. Water vapours condense around fine particulates and gaseous materials dissolve in water and the entire load of waste materials and gases is brought down with rains or snow. This cleans the atmospheric air.
* Above all, the great importance of water is in the photosynthesis reaction which provides the food material for animals and plants itself and consumes the carbon dioxide to maintain the balance in ecosystem.

Global Distribution of Water: An enormous quantity of water is present on our planet. Of the total estimated water on earth and in its atmosphere, 95% is locked in the lithosphere and sedimentary rocks. Only 5% is actually available for free circulation and about 99% of free water is in oceans. Much of the available water, therefore, is of little use to the mankind as it contains a high percentage of salts. It is mainly precipitation over land's surface in the form of dew, rains or snow which is the most important source of fresh water to the terrestrial life[1].

Water availability and use : Most water we use[1] eventually returns to rivers and streams. The total amount of water taken from a lake, river or aquifer for any purpose is the *withdrawal* of water. Much of this water is employed in nondestructive ways and is returned to circulation in a form that can be used again. *Consumption* is the fraction of withdrawn water that is lost in transmission, evaporation, absorption, chemical transformation, or otherwise made unavailable for other purposes as a result of human use. Much water that is withdrawn but not consumed may be degraded-polluted or heated so that it is unsuitable for other uses.

Clean, fresh water is essential for nearly every human endeavor. Perhaps more than any other environmental factor, the availability of water determines the location and activities of human on earth. *Renewable water supplies* are made up, in general, of surface run off plus the infiltration into accessible freshwater aquifers. About two-third of water carried in the rivers and streams every year occurs in seasonal floods that are too large or violent to be stored or trapped effectively for human uses. Stable run off is the dependable, renewable, year round supply of surface water. Much of this occurs, however, in sparsely inhabited regions or where technology, finances, or other factors make it difficult to use it productively. Still, the readily accessible, renewable water supplies are very large, amounting to some 1,500 cu. km (about 400,000 gal) per person per year worldwide.

We can divide water use into three major sectors: agricultural, domestic and industrial. Of these, agriculture accounts for by far the greatest use and consumption. Worldwide, crop irrigation is responsible for two-third of water withdrawl and 85 percent of consumption. Evaporation and seepage from unlined irrigation canals are the principal consumptive water losses. Agricultural water use varies greatly, of course. Over 90 percent of water used in India is agricultural; in Kuwait, where water is especially precious, only 4 percent is used for crops. In the United States, which has both a large industrial sector and a highly urbanized population, about half of all water withdrawal and about 80 percent of consumption is agricultural.

Worldwide, domestic water use accounts for about one-fifth of water withdrawals. Because little of this water evaporates or seeps into the ground, consumptive water use is slight, about 10 percent on average. Where sewage treatment is unavailable, water is badly degraded by urban uses, however. In wealthy countries, each person uses about 500 to 800 L per day (180,000 to 280,000 L per year), far more than in developing countries (30 to 150 L per day).

Industry accounts for 20 percent of global freshwater withdrawals. Industrial use rates range from 70 percent in industrialized parts of Europe to less than 5 percent in countries with little industry. Power production, including hydropower, nuclear and thermoelectric power make up 50 to 70 percent of industrial uses, and industrial processes make up the remainder. As with domestic water, little of this water is made unavailable after use, but it is often degraded by defouling agents, chlorine, or heat when it is released to the environment.

Freshwater Reservoirs

Glaciers, ice and snow : Glaciers, ice and snow contains most of the fresh water[1] of the 2.4 percent of all water that is fresh, nearly 90% is tied up in glaciers, ice caps and snowfields. Glaciers are really rivers of ice flowing downhill very slowly. They now occur only at high altitudes or high latitudes, but as recently as 18,000 years ago about one-third of the continental landmass was covered by glacial ice sheets. Most of this ice has now melted and the largest remnant is in Antarctica. As much as 2 km thick, the Antarctic glaciers cover all, but the highest mountain peak contain nearly 85% of all ice in the world.

A smaller ice sheet on Greenland, together with floating sea ice around the North Pole, makes up another 10 percent of the world's frozen water reservoirs. Mountain snow pack and ice constitute the remaining 5 percent.

Groundwater : Groundwater stores most fresh, liquid water. After glaciers, the next largest reservoir of fresh water is held in the water as groundwater.

Freshwater Shortages : In 1977, the United Nations water Conference declared that all people, regardless of their social or economic conditions, have a right to the clean drinking water and basic sanitation needed to prevent communicable diseases and provide for basic human dignity. Three and half decades later, however, an estimated 1.5 billion people lack access to adequate quantity and quality of drinking water, while nearly 3 billion, or half the world's population, do not have acceptable sanitation. As population grow, more people move into cities, and agriculture and industry compete for increasingly scarce water supplies, water shortages are expected to become, even worse in the future. A country in which consumption exceeds more than 20 percent of the available renewable supply is considered vulnerable to *water stress.*

Globally, water supplies are abundant but unevenly distributed, and the capital needed to collect, store, purify and distribute water is unavailable in many developing countries. Worldwide, water consumption has increased six fold over the past century, or about twice as fast as population growth. With easily accessible water already exploited in most places, the World Bank estimates that the financial and environmental costs of tapping new supplies will be two to three times more expensive than current water projects. If present trend continue the UN cautions, some two-thirds of the world's population will live in countries experiencing water shortages by 2025.

Groundwater : A part of the rain water, which reaches the surface of the earth, percolates into the earth. As this water journeys downwards, it comes in contact with a number of mineral salts present in the soil and dissolves some of them. Water continues its downwards journey, till it meet a hard rock, when it retreads upwards and it may even come out in the form of spring.

Spring and well water (or underground water), in general, is clear in appearance due to the filtering action of the soil, but contains more of the dissolved salts. Thus, water from these sources contains more hardness. Usually, underground water is of high organic purity if it is not contaminated otherwise.

The groundwater is one of the most important source available for water. Groundwater has been harnessed by men ever since he appeared on the earth. Comfortably warming hotwater springs in cold mountainous regions to oasis in dry and desolate deserts were located and used. The "Vedas" and the "Upanishads" which constitute the ancient Hindu literature contain hymns referring to precipitation as the source of all waters and to the concept of what we now recognize as the "hydrological cycle" and to the role of solar energy in driving it. Recorded history of over 5000 years shows evidence of open wells and other hydraulic structures tapping groundwater in China, India and Iran. Some of the sages like Varahamihira in India codified their keen observations on groundwater occurrence and movement.

Groundwater has several advantages over surface water. The space required for any groundwater structures is very little, whether it is in the form of an open well, tube well, radial well or a cavity well; even the largest structure in the form of large diameter open well rarely exceeds 15 meters in diameter. It is a gift of antiquity with plurality of installations scattered throughout in our countryside. It has a constant temperature, dependable colour, taste and odour with hardly any admixture of clay, mud or silt. It has a constant chemical composition and it is generally free from pathogenic, radiochemical and other poisonous contamination. Being a replenishable mineral, it is easily amenable to conservation, artificial recharge and augmentation. Indeed, large storage of ground water to the extent of almost 10 times the precipitation still remains to be tapped[5]. It is perennial source which starts repaying from the time the first potential groundwater structure is installed in a proven belt of potential groundwater reservoir. In fact, civilization started with the first usage of groundwater, and it should survive by making its surrounding green in a calculated venture of Green Revolution with the optimum use of it[6].

The occurrence of groundwater is not merely a product of chance, but it is a product of climatic, hydrologic, geologic, topographic, ecologic and soil-forming factors that together form an integrated dynamic system. These factors are interrelated in such a way that they provide some insight into the function of the total system and serve as indicators of local conditions of groundwater occurrences.

Groundwater amount to 30% of the world's total fresh water resources and represent more than 90% of readily available fresh water. Groundwater has major share in meeting the water requirement for human consumption. This groundwater resources, mainly meet the requirement of potable water in the Indo-Gangetic plain. On global scale also, almost one fifth of all water used in the world at present is obtained from groundwater. Utilization of groundwater by civilization has already been proved in Mohanjodaro and Harrapa besides being referred in Vedic literature. Several researches carried out study on groundwater sample from different parts of India[7-13].

The groundwater is largest single source of water supply and amounts to more than 1 million cubic mile compared to the 30,000 cubic meter of world's stream, rivers and fresh water lakes.

India is rich in groundwater resources and this resource is underutilized. The quantitative and qualitative availability of groundwater is generally influenced by various controlling factors viz., geology, physiography and climatic condition. India's total replenishable groundwater resources are 4318850 m.ha.m/yr and the level of groundwater development is about 32 percent.

Water resources available in the country are as valuable as land and mineral resources and it assumes greater importance in our country because 70% of our people depend on agriculture. Water is needed for irrigation, as monsoon provides rainfall for about four months only and is highly variable and unpredictable. Water resources are also essential for power, agriculture and in large quantity for domestic use. In India, average annual rainfall is about 118 cm. About 80% of the rainfall is received during monsoon only. The total rainfall of Indian territory is estimated to be about 3,700,400 million cubic meter. Of this quantity, about 33% is lost by evaporation, about 22% is lost by seepage and balance moving in the river system and of the rest that seeps into ground, only 333500 million cubic meter recharges the groundwater.

In Bihar, total Replenishable Groundwater Resources are 335213 m.h.m/yr[14] and the utilizable groundwater resources for irrigation in Wet Term are 256439.

Groundwater in the Indo-Gangetic plains, including Araria district in Bihar, serves as a primary source of potable and irrigation water. The increasing reliance on groundwater, driven by rapid population growth and agriculture-intensive practices, has raised concerns over its quality and sustainability. Araria, situated in the northern part of Bihar and bordered by the Kosi and Parman rivers, is part of a hydrologically dynamic region influenced by sedimentary deposits and fluctuating water tables.

While extensive groundwater quality assessments have been conducted in other parts of Bihar, Araria remains relatively under-explored. The presence of geogenic contaminants like arsenic, fluoride, and iron in neighboring districts indicates a high potential for similar groundwater quality challenges in Araria. This review synthesizes available data and literature to provide a comprehensive overview of groundwater quality concerns in the region.

Study Area

Araria district[15] is located between latitudes 26°442' – 27°522' N and longitudes 87°022' – 87°522' E. It comprises nine blocks: Araria, Bhargama, Forbesganj, Jokihat, Kursakanta, Narpatganj, Palasi, Raniganj, and Sikty. The district lies within the Kosimegafan region, characterized by flat topography, silty clay soils, and shallow unconfined aquifers. The climate is humid subtropical with high monsoonal rainfall, contributing to variable recharge rates.

Methodology

This study employs a review methodology, collating data from multiple sources including:

- **Central Ground Water Board (CGWB) reports** on aquifer mapping and groundwater resource assessment[16].
- **Peer-reviewed research articles** addressing groundwater quality in Bihar.
- **Government publications and grey literature** on water quality standards and contamination risks.
- **Regional comparative studies** from nearby districts with similar geological settings. Parameters of interest include pH, Total Dissolved Solids (TDS), iron, fluoride, arsenic, and other hydrochemical constituents. Where primary data for Araria is missing, inferences are drawn from similar lithological and hydrological zones in adjacent districts.

Hydrogeological Characteristics

According to CGWB's 2021 aquifer mapping report, Araria has a shallow alluvial aquifer system with potential yields of 20–30 tube wells per square kilometer. The water table varies between 2 to 8 meters below ground level (mbgl) during pre- and post-monsoon periods. Aquifers are largely unconfined and composed of fine to coarse sand, with occasional clay lenses.

Notably, parts of the district face waterlogging due to poor drainage and extensive irrigation, particularly in areas under canal command. This stagnation may contribute to the mobilization of contaminants from sediments into groundwater.

Groundwater Quality Review

Arsenic Contamination: The presence of arsenic in groundwater is a major concern in Bihar[17,18], mainly in the districts like Bhagalpur, Katihar, and Purnia reporting levels above the permissible limits of 10 µg/L (WHO) and 50 µg/L (BIS). Although Araria lacks direct testing data in public reports, similar sedimentary environments and aquifer conditions strongly suggest potential arsenic presence, especially in shallow tube wells.

Iron and Fluoride: Iron concentrations in groundwater across Bihar frequently exceed the permissible limit of 0.3 mg/L, causing discoloration, taste issues, and staining. Fluoride, linked to dental and skeletal fluorosis, has been detected at hazardous levels (>1.5 mg/L) in adjacent areas. CGWB data from Bihar indicates sporadic high fluoride zones that may extend into Araria.

Other Hydrochemical Parameters: Available CGWB and research data for Bihar[19] show that groundwater in the region generally has neutral to slightly alkaline pH (6.5–8.5) and TDS levels within safe limits for most locations. However, high nitrate levels have been noted in areas with inadequate sanitation and excessive fertilizer use.

Health and Agricultural Impacts

Prolonged exposure to arsenic and fluoride through drinking water leads to severe health outcomes including cancers, developmental issues, and bone deformities. Elevated iron, although less toxic, affects water usability and consumer acceptability. For agriculture, high iron and fluoride can reduce crop productivity and soil fertility. These risks underline the need for targeted water quality management in Araria.

Geospatial and Monitoring Approaches

Recent studies in districts like Sheikhpura, Bihar have used GIS and geostatistical methods (Kriging, Inverse Distance Weighting) to model contaminant spread and identify hotspots. Applying such approaches in Araria could support evidence-based planning and mitigation. Moreover, block-level sampling and real-time monitoring systems are essential to assess temporal variations in water quality.

Recommendations

* **Comprehensive District-Wide Sampling:** Initiate a coordinated groundwater sampling campaign across all nine blocks.
* **Contaminant Mapping:** Use GIS-based modeling to identify and monitor contaminant zones.
* **Community Awareness Programs:** Educate the public on groundwater contamination and promote safe water practices.
* **Water Treatment Interventions:** Deploy household-level arsenic/iron removal units and promote deeper aquifer tapping where appropriate.
* **Policy Integration:** Incorporate groundwater quality data into local planning, especially in rural water supply schemes.
* **Recharge Enhancement:** Promote rainwater harvesting and managed aquifer recharge to dilute contaminant loads.

Conclusion

Groundwater in Araria district remains a vital yet vulnerable resource. While available hydrogeological assessments reveal favorable aquifer conditions, quality risks—especially from arsenic, iron, and fluoride—require urgent attention. This review calls for systematic data collection, adoption of geospatial tools, and decentralized mitigation strategies to ensure safe and sustainable groundwater use in Araria.

10. Conflict of Interest

The author declares no conflict of interest.

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