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Assessment of Arsenic Contamination in Groundwater in Selected Villages of Naugachia Koshi Region, Bhagalpur, Bihar, India

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Abstract

Arsenic contamination of groundwater is a serious public health concern in the koshi plains of Bihar, India. The present study was conducted to assess the concentration of arsenic along with key physicochemical parameters electrical conductivity and total hardness in groundwater samples collected from three villages, namely Punama, Shripur, and Dhobiniya, located in the Naugachia Block of Bhagalpur District, Bihar. A total of 30 groundwater samples (10 per village) were collected from handpumps and shallow tube-wells. Arsenic concentration was determined using the Merckoquant semi-quantitative test kit method. Electrical conductivity (EC) was measured using a calibrated EC meter, and total hardness was determined by acid-base titration using N/50 HCl with methanol as indicator. Results revealed arsenic concentrations ranging from not detectable (ND) to 0.070 ppm in Dhobiniya, 0.010–0.050 ppm in Shripur, and ND–0.030 ppm in Punama. Several samples from Dhobiniya and Shripur exceeded the WHO guideline value of 0.010 ppm and approached or exceeded the BIS permissible limit of 0.050 ppm, indicating a significant public health risk. Conductivity values were highest in Dhobiniya (up to 1.72 mS/cm), suggesting elevated dissolved ionic load. Hardness followed the trend Dhobiniya > Shripur > Punama, with Dhobiniya water classified as moderately to very hard. The study underscores the urgent need for continuous groundwater monitoring, community awareness, and installation of arsenic removal units in the affected villages.

Keywords: Arsenic contamination, groundwater quality, Merckoquant kit, electrical conductivity, total hardness, Naugachia, Bhagalpur, Bihar, Koshi plains

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Introduction

Arsenic (As) is a naturally occurring metalloid widely distributed in the Earth's crust. Chronic exposure to arsenic through contaminated drinking water is associated with severe health effects, including arsenicosis, skin lesions, peripheral neuropathy, keratosis, and cancers of the skin, bladder, lung, and kidney. The World Health Organization (WHO) has set a guideline value of 0.010 mg/L (10 µg/L) for arsenic in drinking water, while the Bureau of Indian Standards (BIS) has stipulated a permissible limit of 0.050 mg/L (50 µg/L) in the absence of an alternative source [1], [2], [3]. The Koshi Plains of Bihar represent one of the world's most severely arsenic-affected regions. The problem in Bihar is geogenic in origin as well as channelization of flood water with groundwater and is largely confined to the districts situated along the southern bank of the Koshi River [4]. Bhagalpur District has been identified as one of the affected districts, with the alluvial aquifers of its low-lying areas showing elevated arsenic levels attributable to the reductive dissolution of iron oxyhydroxides that carry naturally adsorbed arsenic into the groundwater [5] [6], [7], [8]. Naugachia which is situated in the northern part of Bhagalpur District adjacent to the Ganga floodplain, is particularly vulnerable to arsenic contamination owing to its young alluvial geological setting, shallow water table, and predominant dependence on groundwater for drinking and domestic purposes. Despite the documented arsenic problem in the broader Bhagalpur region, village-level groundwater quality data for Naugachia remain sparse in the scientific literature [5], [9], [10]. The Koshi River is one of the major rivers of northern India and Nepal, originating in the Himalayas of Tibet and Nepal. It is a tributary of the Ganges River and is often called the “Sorrow of Bihar” because of its frequent floods and changing course. The river carries a large amount of silt from the Himalayas, making the surrounding plains highly

fertile for agriculture. The Koshi River supports irrigation, fishing, and the livelihood of millions of people living in Bihar and Nepal.

Study Area

The study was conducted in three villages Punama, Shripur, and Dhobiniya as shown in map fig.1. located within Naugachia (approximately 25°23'N, 87°06'E) of Bhagalpur District, Bihar, India. Naugachia Block lies in the northern portion of the district and is bounded to the north by the River Ganga. The area falls in the Middle of Koshi and Ganga Plain, characterised by recent alluvial deposits of Quaternary age comprising sand, silt, and clay layers. The region experiences a humid subtropical climate with hot summers, a monsoon season from June to September, and mild winters. Mean annual rainfall is approximately 1,100–1,300 mm. The water table is shallow, typically 2–8 m below ground level, and the local populace relies heavily on handpumps and shallow tube-wells (40–100 ft depth) for drinking water. The three study villages are primarily agricultural, with paddy and wheat cultivation as the main occupation. There is minimal industrial activity in the vicinity, confirming that the source of arsenic contamination is geogenic rather than anthropogenic. The three villages are spatially distributed across the block Punama lies in the western sector, Shripur in the central sector, and Dhobiniya in the eastern sector of the study area, providing a reasonable spatial coverage for groundwater quality assessment across the block.

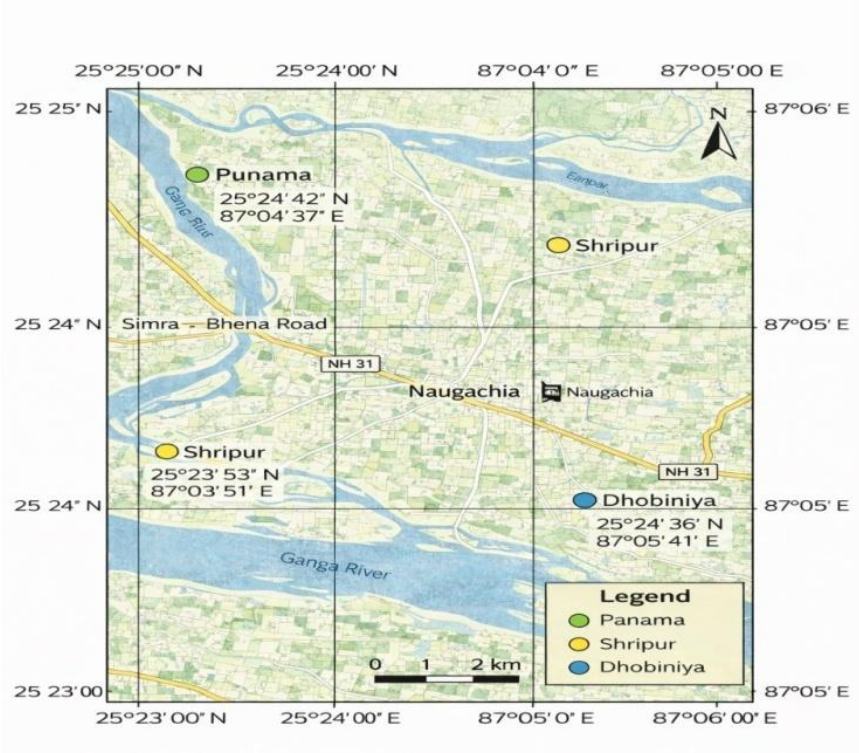


Figure 1 Location of Punama, Shripur and Dhobiniya villages.

Materials and Methods

Sample Collection

Groundwater samples were collected from 30 locations across the three study villages: 10 samples each from Punama (S1–S10), Shripur (S11–S20), and Dhobiniya (S21–S30). Samples were drawn from operational handpumps and shallow tube-wells after allowing the pump to run for at least 2–3 minutes to flush stagnant water from the pipe column. Samples were collected in pre-cleaned, acid-washed, deionised-water-rinsed polyethylene bottles of 500 mL capacity. For arsenic analysis, samples were preserved with 0.5 mL of concentrated HNO_3 per litre to prevent oxidation and precipitation of dissolved arsenic. Conductivity and hardness measurements were performed on fresh, unpreserved samples within 6–8 hours of collection. Sampling locations were recorded using a GPS device.

Arsenic Analysis (Merckoquant Kit Method)

Arsenic concentrations were determined using the Merckoquant Arsenic Test semi-quantitative field kit (Merck KGaA), which is based on the classical Gutzeit method. The principle of the method is as follows: arsenic species (arsenite and

arsenate) present in the water sample are reduced to arsine gas (AsH_3) by reaction with zinc granules in an acidic medium (hydrochloric acid). The liberated arsine gas passes through a lead acetate-impregnated cotton wool plug (to remove hydrogen sulphide) and reacts with a mercury(II) bromide ($HgBr_2$)-impregnated test strip. The reaction produces a yellow-to-brown stain on the strip, the intensity of which is proportional to the arsenic concentration in the sample. The colour developed on the test strip was compared against the standard colour chart provided with the kit (range: 0.005–0.500 mg/L). Each test was performed in triplicate and the mean value is reported in mg/L (ppm). Concentrations below the kit's detection limit (~0.005 mg/L) are reported as Not Detected (ND).

Electrical Conductivity (EC Meter Method)

Electrical conductivity (EC) is a measure of the ability of water to conduct an electric current and is directly proportional to the concentration of dissolved ionic species (total dissolved solids, TDS). EC was measured using a calibrated digital EC meter. Before each measurement, the probe was rinsed with deionised water and blotted dry. A measured volume of sample was taken in a clean beaker, the probe was immersed to the required depth, and the reading was recorded in mS/cm (millisiemens per centimetre) after stabilisation. The instrument was calibrated using a standard KCl solution (1413 µS/cm at 25°C). All readings were temperature-corrected to 25°C.

Total Hardness (N/50 HCl Titration with Methanol Indicator)

Total hardness of water is caused principally by dissolved Ca^{2+} and Mg^{2+} ions. In the present study, hardness was determined by titrimetric analysis using standard N/50 (0.02 N) hydrochloric acid solution with EDTA as indicator. The procedure was as follows: a 50 mL aliquot of the water sample was pipetted into a clean conical flask. The sample was then titrated against standard N/50 HCl solution taken in a burette. The titration was performed slowly with constant swirling until the endpoint, indicated by a distinct colour change, was reached. The volume (V mL) of N/50 HCl consumed was recorded. Results are expressed in grams (gm/L) equivalent, corresponding to the volume of N/50 HCl consumed. All titrations were performed in triplicate and mean values are reported.

Results and Discussion

Arsenic Concentration in Groundwater

The arsenic concentrations measured across all 30 samples are presented in Table 1. A total of 17 out of 30 samples (56.7%) had detectable arsenic, and several exceeded the WHO guideline value of 0.010 ppm [11] [12].

Table 1 Arsenic concentration (ppm) in groundwater samples from Punama, Shripur, and Dhobiniya villages

Sample	Punama (ppm)	Sample	Shripur (ppm)	Sample	Dhobiniya (ppm)
S1	ND	S11	0.010	S21	ND
S2	0.020	S12	0.020	S22	ND
S3	ND	S13	ND	S23	0.050
S4	ND	S14	ND	S24	0.040
S5	ND	S15	0.050	S25	ND
S6	ND	S16	0.020	S26	**0.070**
S7	0.020	S17	ND	S27	ND
S8	0.030	S18	0.050	S28	0.020
S9	0.020	S19	0.050	S29	0.050
S10	ND	S20	0.020	S30	0.020

In Punama village, arsenic concentrations ranged from ND to 0.030 ppm (mean ~0.014 ppm) shown in Fig.2. Detectable arsenic was found in samples S2, S7, S8, and S9. While 40% of Punama samples exceeded the WHO guideline of 0.010 ppm, none reached the BIS permissible limit of 0.050 ppm [13]. This suggests that Punama is at moderate risk and requires regular monitoring. In Shripur village, arsenic ranged from 0.010 to 0.050 ppm (mean ~0.022 ppm) Fig.3. A striking 80% of samples had detectable arsenic. Three samples (S15, S18, S19) recorded 0.050 ppm, exactly at the BIS permissible limit. Samples S12, S16, and S20 recorded 0.020 ppm, and S11 recorded 0.010 ppm. The consistent arsenic detection across Shripur indicates a spatially widespread contamination pattern in its aquifer. Dhobiniya village in Fig.4 exhibited the most severe contamination. Arsenic concentrations ranged from ND to 0.070 ppm (mean ~0.025 ppm). Sample S26 recorded the highest value of 0.070 ppm, exceeding the BIS permissible limit of 0.050 ppm by 40% and the WHO guideline by seven-fold. Samples S23 and S29 also reached the BIS limit at 0.050

ppm. The spatial heterogeneity some samples ND, adjacent samples highly elevated is characteristic of alluvial aquifer arsenic contamination driven by localised reducing microenvironments, where reductive dissolution of arsenic-bearing iron oxyhydroxides mobilises arsenic selectively depending on the local redox chemistry, organic carbon content, and groundwater flow patterns.

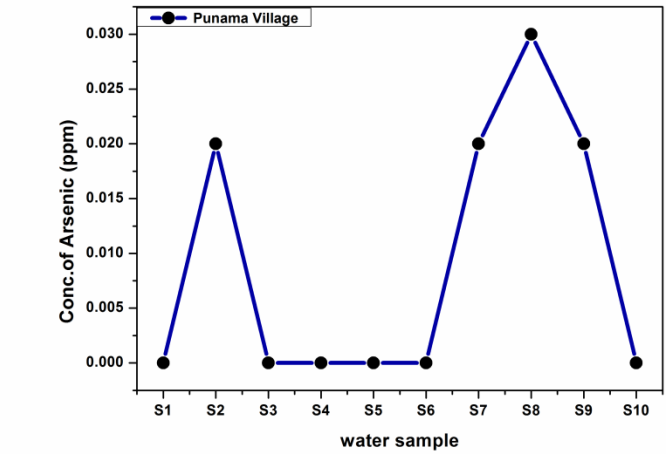


Figure 2 Concentration of Arsenic in Punama Village

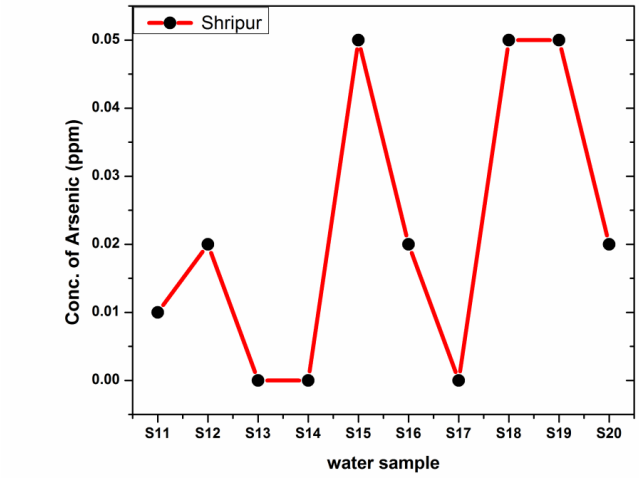


Figure 3 Concentration of Arsenic in shripur village

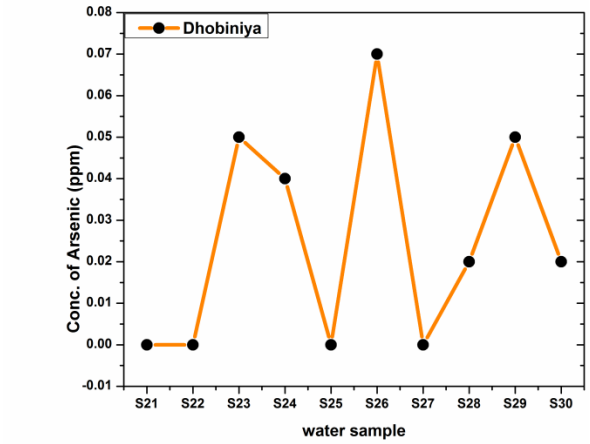


Figure 4 Concentration of Arsenic in Dhobiniya village

Electrical Conductivity

Electrical conductivity results are presented in Table 2.

Table 2 Electrical conductivity (mS/cm) in groundwater samples from Punama, Shripur, and Dhobiniya villages

Sample	Punama (mS/cm)	Sample	Shripur (mS/cm)	Sample	Dhobiniya (mS/cm)
S1	0.72	S11	0.78	S21	0.51
S2	0.59	S12	0.49	S22	0.68
S3	0.65	S13	0.46	S23	0.42
S4	0.51	S14	0.56	S24	0.43
S5	0.47	S15	0.45	S25	0.65
S6	0.42	S16	0.69	S26	0.77
S7	0.82	S17	0.50	S27	1.58
S8	0.63	S18	0.84	S28	**1.72**
S9	1.00	S19	0.49	S29	1.00
S10	0.63	S20	0.50	S30	1.26

In Punama, EC ranged from 0.42 to 1.00 mS/cm (mean 0.664 mS/cm), well within permissible limits. Shripur showed a range of 0.45–0.84 mS/cm (mean 0.576 mS/cm), also within limits. Dhobiniya recorded the widest and highest EC range (0.42–1.72 mS/cm, mean 0.902 mS/cm), with samples S27 (1.58 mS/cm) and S28 (1.72 mS/cm) exceeding the permissible threshold of 1.5 mS/cm. High EC values in Dhobiniya indicate elevated dissolved ionic loads, likely comprising bicarbonates, chlorides, and sulphates of calcium, magnesium, sodium, and potassium derived from mineral dissolution in the alluvial aquifer. The co-occurrence of high EC with elevated arsenic in the S26–S28 cluster of Dhobiniya is noteworthy and strongly suggests coupled hydrogeochemical processes: the same reducing conditions that mobilise arsenic from iron oxyhydroxides also dissolve accompanying mineral phases, increasing overall ionic strength and conductivity [14] [15].

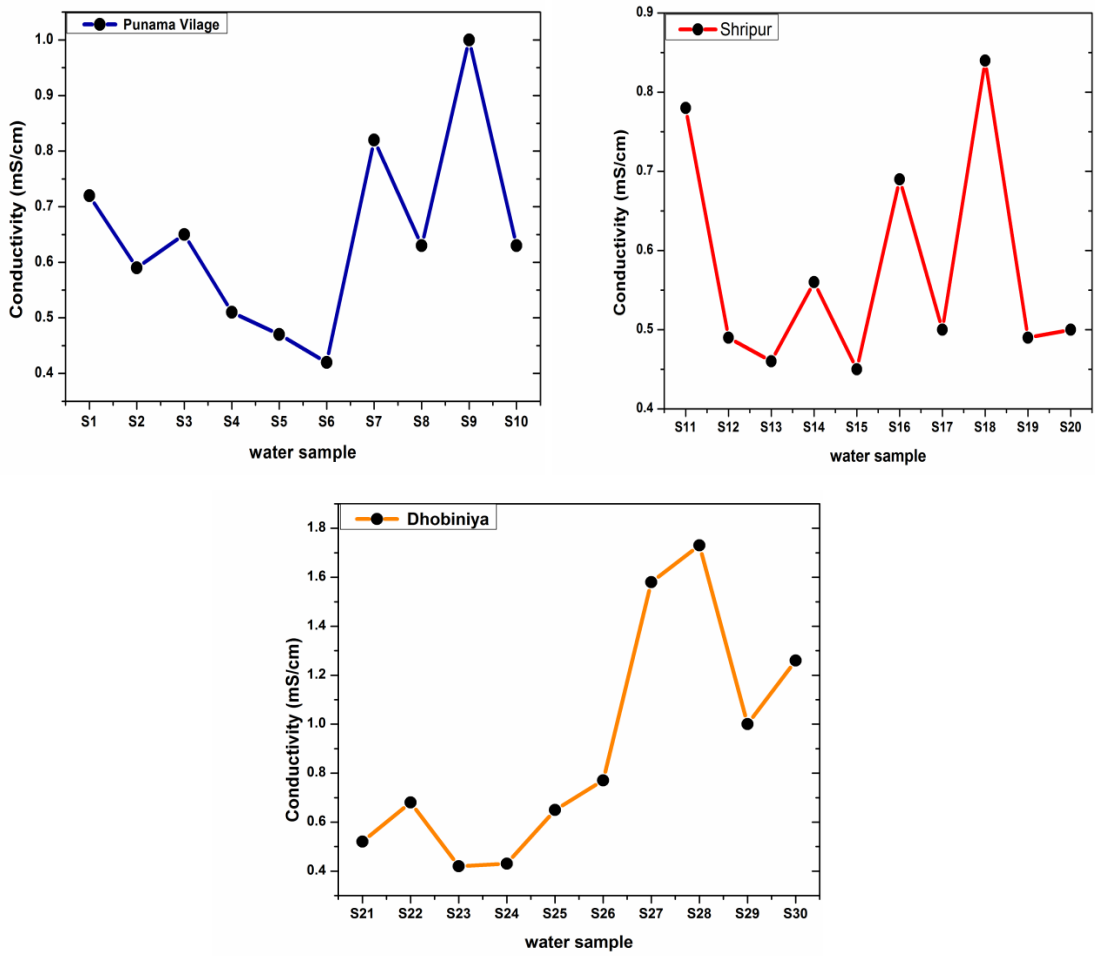


Figure 5 Conductivity in Punama, Shripur and Dhobiniya village

Total Hardness

Hardness results from all three villages are given in Table 3.

Table 3 Total hardness (mg/L) in groundwater samples from Punama, Shripur, and Dhobiniya villages

Sample	Punama (mg/L)	Sample	Shripur (mg/L)	Sample	Dhobiniya (mg/L)
S1	16.0	S11	44.0	S21	40.0
S2	15.5	S12	40.0	S22	40.0
S3	17.0	S13	42.0	S23	37.5
S4	16.0	S14	40.0	S24	35.0
S5	16.0	S15	42.0	S25	40.0
S6	18.5	S16	42.0	S26	43.0
S7	19.5	S17	40.0	S27	47.0
S8	13.5	S18	40.0	S28	**61.0**
S9	14.5	S19	40.0	S30	51.0
S10	13.0	S20	36.0	S30	49.0

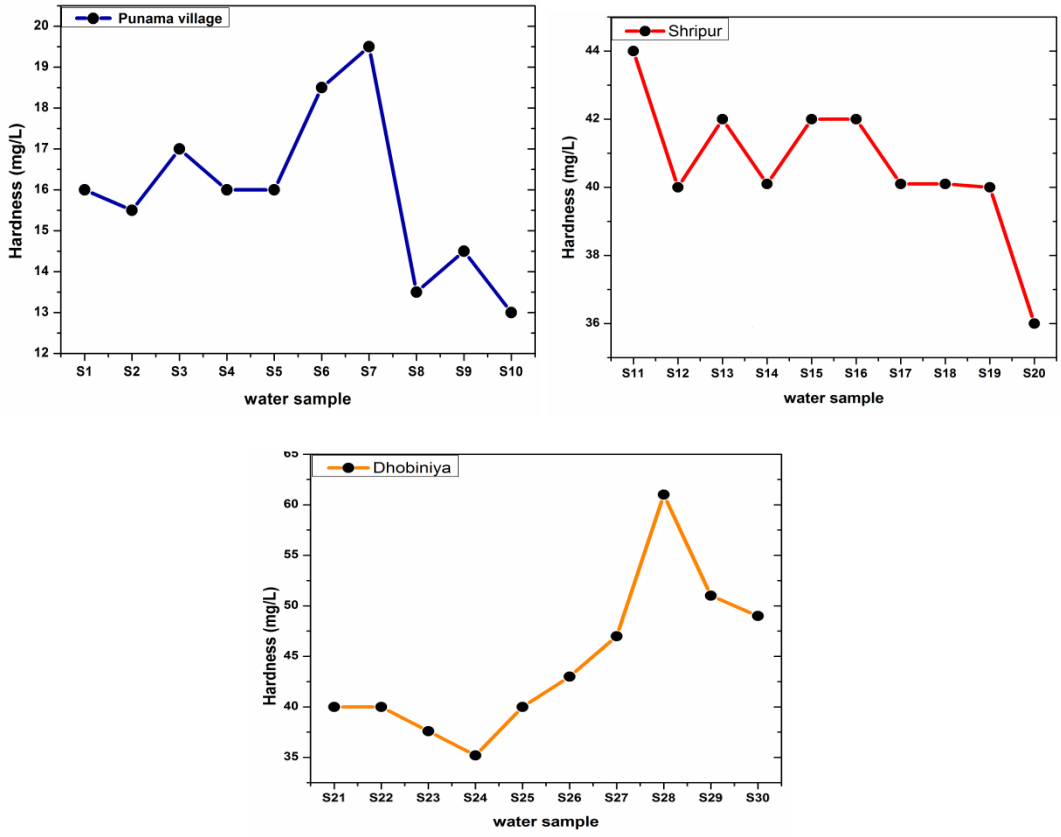


Figure 6 Hardness of Groundwater in Punama, Shripur and Dhobiniya village

Table 4 Summary statistics and comparison of three villages

Parameter	Village	Mean ± SD	Median
As (ppm)	Punama	0.009 ± 0.012	0.000 (ND)
	Shripur	0.022 ± 0.021	0.020
	Dhobiniya	0.025 ± 0.026	0.020
EC (mS/cm)	Punama	0.644 ± 0.172	0.63
	Shripur	0.576 ± 0.142	0.50
	Dhobiniya	0.902 ± 0.472	0.725
Hardness (mg/L)	Punama / Shripur / Dhobiniya	15.95 ± 2.03 / 40.6 ± 2.1 / 44.35 ± 7.8	16.0 / 40.0 / 41.5

Punama recorded the lowest hardness (13.0–19.5 gm, mean 15.95 gm), classifying its groundwater as soft. This is consistent with low mineral content in the shallow aquifer and correlates with the lowest EC values among the three villages. Soft water, while acceptable for drinking, may have a slightly corrosive character and a lower buffering capacity. Shripur showed uniform and moderate hardness values (36.0–44.0 mg/L, mean 40.6 mg/L). The consistency across samples suggests a homogeneous aquifer mineralogy throughout the village. Sample S11 recorded the highest value of 44.0 mg/L in this village. Dhobiniya recorded the highest hardness overall (35.0–61.0 mg/L, mean 44.35 mg/L).

The peak value of 61.0 mg/L at S28 — coinciding with the highest EC of 1.72 mS/cm at the same location confirms a zone of intense mineral dissolution at that sampling point. The trend of increasing hardness from S21→S28 and subsequent decrease towards S30 traces a spatial gradient across the village that likely reflects proximity to a mineralogically enriched horizon or a zone of preferential groundwater flow and mineral weathering [16].

The table clearly establishes that Dhobiniya is the most critically affected village across all three parameters. The overall contamination severity follows the order Dhobiniya > Shripur > Punama.

Conclusions

The present study provides important baseline groundwater quality data for three villages in Naugachia Block, Bhagalpur District, Bihar. The key findings are: Arsenic contamination is a significant public health concern across all three villages. Contamination severity follows the order Dhobiniya (max 0.070 ppm) > Shripur (max 0.050 ppm) > Punama (max 0.030 ppm). Multiple samples from all three villages exceed the WHO guideline of 0.010 ppm, and samples from Dhobiniya and Shripur reach or exceed the permissible limit of 0.050 ppm. Dhobiniya groundwater shows the highest electrical conductivity (up to 1.72 mS/cm), with two samples exceeding the WHO acceptable limit of 1.5 mS/cm, indicating elevated dissolved ionic loads and a higher degree of aquifer mineral dissolution. Total hardness follows the pattern Dhobiniya > Shripur > Punama. Punama groundwater is characteristically soft (13–19.5 mg/L), while Dhobiniya groundwater approaches a moderately hard classification, consistent with higher mineral content. The co-elevation of arsenic, conductivity, and hardness at sample cluster S26–S28 in Dhobiniya indicates coupled hydrogeochemical processes, most likely reductive dissolution of arsenic-bearing iron oxyhydroxides alongside carbonate and silicate mineral weathering in a locally reducing aquifer environment. Population of the villages under study is facing the risk of adverse health effects of arsenic such as skin hyperpigmentation but no case of this symptoms has been traced in these villages.

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