



International Journal of Geography, Geology and Environment

P-ISSN: 2706-7483

E-ISSN: 2706-7491

NAAS Rating (2025): 4.5

IJGGE 2026; 8(1): 34-39

www.geojournal.net

Received: 06-10-2025

Accepted: 18-11-2025

Noor Fatma

Department of Zoology,
Babasaheb Bhimrao
Ambedkar Bihar University,
Muzaffarpur, Bihar, India

Braj Kishor Prasad Singh

Department of Zoology,
Babasaheb Bhimrao
Ambedkar Bihar University,
Muzaffarpur, Bihar, India

Corresponding Author:

Braj Kishor Prasad Singh

Department of Zoology,
Babasaheb Bhimrao
Ambedkar Bihar University,
Muzaffarpur, Bihar, India

Assessment of borehole water quality in different areas of the Musahari block, Muzaffarpur

Noor Fatma and Braj Kishor Prasad Singh

DOI: <https://doi.org/10.22271/27067483.2026.v8.i1a.470>

Abstract

Borehole water is the most precious natural resource on Earth. It is widely used for drinking and other anthropogenic activities. The deteriorating quality of borehole water is becoming an important concern. This study focuses on the quality of borehole water in the Musahari Block of Muzaffarpur. Fifteen water samples were collected during the pre-monsoon season and analyzed for physicochemical parameters, including pH, TDS, TA, turbidity, EC, TH, Ca^{2+} , Mg^{2+} , Cl^- , SO_4^{2-} , NO_3^- , As, Fe^{2+} , F^- , and a microbial parameter, namely total coliform, measured using standard procedures to assess its current quality status. The results obtained from the sample analysis were compared with the drinking water quality standards set by BIS and WHO. The analysis revealed elevated levels of physicochemical parameters such as TDS, alkalinity, turbidity, and iron, while some parameters fell below the acceptable range, underscoring the need for improved water treatment. Therefore, suitable mitigation measures should be adopted to enhance the water quality in the polluted area. The health risks associated with these parameters were also assessed.

Keywords: Borehole water, physical parameter, chemical parameter, heavy metals, microbial parameter

Introduction

Water is the most crucial resource for multitudinous life on this planet and is necessary for maintaining life on Earth. Approximately 97% of the planet's total water is saline, leaving only 3% as freshwater. However, of this 3%, merely 0.01% is easily accessible for human use. Groundwater, which makes up 99% of available freshwater, is the primary source of drinking water, with boreholes being a standard means of access [Azizullah *et al.*, 2011] ^[5]. It is one of the most valuable sources of drinking water, extensively used in many regions worldwide. It serves various purposes, including domestic, agricultural, and industrial activities. Groundwater meets 42% of farming and 27% of industrial demands worldwide. At the same time, nearly one-third of the global population relies on it for drinking and domestic use [Nickson *et al.*, 2005; Verma *et al.*, 2020] ^[19, 25].

More than 85% of drinking water supplies typically come from groundwater resources, and many urban and rural residents in India rely solely on groundwater. Growing populations, rapid economic expansion, and higher living standards have resulted in an ever-increasing demand for fresh water (Moussa *et al.*, 2020; Shi *et al.*, 2018) ^[3, 26]. Groundwater plays a critical role in India, meeting 85% of rural drinking water needs, 62% of agricultural irrigation, and 45% of urban water demand (Verma *et al.*, 2020) ^[24]. India's water crisis has worsened since 2017, when contaminated water caused 569,679 deaths (47.5% of the global 1.2 million fatalities). Recent estimates suggest over 650,000 annual deaths in 2023–24, with groundwater contamination now linked to approximately 60% of cases—primarily due to arsenic, fluoride, and industrial pollutants in states like Bihar, West Bengal, and Punjab (Ritchie & Roser, 2019; [Latest WHO/UNICEF/WRI Report, 2024]).

Bihar, an agrarian state in Eastern India, lies within the Ganga-Meghna-Brahmaputra (GMB) basin, where groundwater serves as the primary source of drinking water, fulfilling over 80% of rural water needs. Of the 38 districts, 22 are severely impacted by arsenic contamination, exposing over half of the state's population to this critical health hazard [Kumar *et al.*, 2021; Richards LA, 2020] ^[12, 22]. Bihar's water-related death rate (11.97%) towers 56% above the national average (7.65%), exposing critical failures in groundwater protection (The Times of India, 2018).

In this new era of rapid development, population growth, and urbanization, groundwater pollution is being exacerbated by the expansion of industrial sectors, excessive use of fertilizers in irrigation, inadequate sewage systems, urban construction, and the disposal of human and animal waste. [Gao *et al.*, 2020; Lapworth *et al.*, 2012; Zhang *et al.*, 2020; Adimalla *et al.*, 2020] ^[23, 18, 23, 18]. The recently tabled Bihar Economic Survey (2024-25) revealed alarming groundwater contamination across the state, with arsenic detected in 4,709 wards, fluoride in 3,789 wards, and excessive iron in 21,709 wards. Thus, consistent monitoring and testing of water samples are crucial to verify the safety and purity of groundwater.

Materials and Methods

Study site

Muzaffarpur is a major urban center in Bihar, serving as both the district headquarters of Muzaffarpur and the administrative seat of Tirhut Division. Situated along the Budhi Gandak River in northern Bihar, it ranks as the state's fourth most populous city. Muzaffarpur is located at a latitude of 26°07'North 85°24'E. This study primarily focuses on the drinking water quality index of Muzaffarpur, a district in Bihar. With approximately 473,000 urban and 4.33 million rural residents, the district's population depends largely on borehole water for drinking purposes. The present study focuses on the borehole water quality of Muzaffarpur. The study was conducted at 15 locations, encompassing residential, industrial, and slum areas. This study examined water quality in 15 boreholes across various locations: Bela (S1), Sadpura (S2), Mithanpura (S3), Motijheel (S4), Brahampura Daudpur (S5), Bela Industrial Area (S6), Bajrang Enterprises Bela Industrial Area (S7), Bela Cold Storage Phase 2 (S8), D3 Phase 2 (S9), B33 Phase 2 (S10), Sikandarpur (S11), Ganipur (S12), Brahampura (S13), Dadar Zero Mile (S14), and Daudpur Kothi (S15).

For the present study, borehole water samples were collected at one-month intervals during the pre-monsoon period (April to June 2024) from 15 different sampling sites, encompassing residential, industrial, and slum areas. Each borehole was pumped 5–10 minutes before collection to remove stagnant water and ensure representative sampling. The samples were then collected in pre-cleaned 1-liter polyethylene containers.

Following standard protocols, the samples were immediately preserved in an icebox and transported to the laboratory within three hours of collection. Upon arrival, they were properly labelled, sealed, and stored at a constant temperature of 4 °C to maintain their integrity until analysis. The collected borehole water samples were analyzed for various Physico-chemical parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, total hardness (TH), total alkalinity (TA), calcium (Ca²⁺), magnesium (Mg²⁺), chloride (Cl⁻), sulphate (SO₄²⁻), nitrate (NO₃⁻), arsenic (As), iron (Fe²⁺), and fluoride (F⁻), following standard methods (APHA). The borehole nozzle was sterilized for microbial analysis using cotton wool soaked in 70% ethanol. Before sampling, each borehole was pumped for 5–10 minutes to remove stagnant water. A 250 mL screw-capped sterile plastic bottle was then carefully uncapped, filled with the sample, and promptly recapped to prevent contamination.

Results and Discussion

The collected samples were analyzed to assess their compliance with drinking water standards set by the Bureau of Indian Standards (BIS) and the World Health Organization (WHO), evaluating both physicochemical and microbial parameters (Table 1) and the result is mentioned in table 2. Notably, total and fecal coliforms were absent in all tested samples, indicating no fecal contamination.

Table 1: Standard values of different water parameters according to Bureau of Indian Standards (BIS) and the World Health Organization (WHO).

Parameters	Acceptable /Desirable Limit (IS 10500-2012)	Permissible Limit in absence of alternate source IS	WHO Standard limit
pH	6.5-8.5	NR	no health based guideline value
Turbidity	1NTU	5NTU	
Electrical Conductivity	750	2500	
Total Dissolved Solid	500 mg/l	2000 mg/l	no health based guideline value
Total Hardness	200 mg/l	600 mg/l	
Calcium	75 mg/l	200 mg/l	
Magnesium	30 mg/l	100 mg/l	
Chloride	250 mg/l	1000 mg/l	
Alkalinity	200 mg/l	600 mg/l	
Iron	0.3 mg/l	NR	no health based guideline value
Sulphate	200 mg/l	400 mg/l	no health based guideline value
Nitrate	45 mg/l	NR	50
Fluoride	1.0 mg/l	1.5 mg/l	1.5s
Arsenic	0.01 mg/l	NR	0.01
Total Coliform, CFU/100 ml	0	5	

pH

The pH level, which indicates the acidity or alkalinity of water by measuring hydrogen ion concentration, ranged between 6.5 and 8.5 across all 15 sampling sites in this study, conforming to both WHO guidelines and Indian Standard (IS 10500:2012) for drinking water. While pH values below 6.5 (acidic) may corrode water infrastructure and values above 8.5 (alkaline) can impart undesirable taste,

all samples remained within the safe, neutral range, demonstrating suitable water quality in terms of pH balance (Goon *et al.*, 1986) ^[10].

Electrical Conductivity

The study recorded electrical conductivity (EC) levels between 640-1346 µS/cm across all water samples, exceeding the BIS permissible limit of 1000 µS/cm at

several locations. These elevated EC values, indicating high dissolved ion concentrations, likely originate from natural mineral dissolution or anthropogenic sources like agricultural/industrial runoff and sewage contamination. While EC itself has no direct health effects, consistently high values may indicate increased TDS, salinity, or inorganic contaminants that require further assessment.

Table 2: Value of different water quality parameter observed from different locations.

Area	pH	Turb.	EC	TDS	TH	Ca	Mg	Cl	Alk	Fe	SO ₄	NO ₃	F
S1	7.79	8.9	1265	820	496	146	32	137	522	2	40	10	0.2
S2	7.56	3.6	920	602	544	162	23	125	510	0.2	30	8	0.2
S3	7.62	4.2	1148	714	552	86	81	199	579	0.3	30	10	0.2
S4	7.81	9.2	1043	696	496	78	71	141	428	1.8	25	6	0.3
S5	7.79	4.1	1070	680	416	130	22	133	473	0.2	26	8	0.2
S6	7.52	2.7	887	576	456	40	85	87	468	0.2	20	5	0.3
S7	7.49	0.8	799	519	424	62	64	46	457	0.2	20	8	0.3
S8	6.98	0.9	1216	789	584	104	78	131	490	0.2	25	10	0.2
S9	7.13	0.5	633	412	352	54	52	50	372	0.3	18	15	0.4
S10	7.42	1.5	640	415	360	54	54	77	428	0.3	18	10	0.4
S11	7.4	4.9	874	568	400	99	37	185	408	1	20	5	0.3
S12	7.28	1.2	1110	720	260	62	25	115	567	0.3	30	5	0.2
S13	7.19	0.4	1346	875	432	128	27	187	563	0.3	25	10	0.3
S14	7.34	0.3	1139	740	428	75	58	81	547	0.2	20	5	0.2
S15	7.58	4.5	773	503	452	45	82	75	481	0.8	20	5	0.2

Total dissolved solids

The study found TDS levels ranging from 503-875 mg/L in water samples, exceeding the BIS desirable limit of 500 mg/L at three sites (S1:820, S8:789, S13:875 mg/L). While

most samples remained within acceptable/desirable limits, elevated TDS can affect water taste, promote pipe corrosion, and disrupt aquatic ecosystems. These results underscore the importance of regular monitoring to maintain water quality standards (Prasad *et al.*, 2019) (Table 1).

Turbidity

Several sampling locations showed elevated turbidity levels (S1:8.9, S4:9.2), nearing the BIS permissible limit (1 NTU to 5 NTU). This indicates potential contamination from suspended particles, organic matter, or soil runoff, which can reduce water clarity, hinder disinfection, and promote bacterial growth (Table 2).

Total alkalinity

The water samples showed total alkalinity levels ranging from 372 to 579 mg/L, within the BIS limit of 600 mg/L but significantly above the desirable 200 mg/L limit. While not a health risk, such elevated alkalinity may impair water taste, promote scaling in plumbing systems, and reduce disinfection efficiency.

Total Hardness: The groundwater samples showed total hardness ranging from 260-584 mg/L, classified as 'acceptable' (<300 mg/L) to 'permissible' (300-600 mg/L) under BIS standards. These variations result from the natural dissolution of calcium/magnesium minerals during groundwater percolation. While posing no health risks, higher values near 600 mg/L may cause scaling, reduce soap efficiency, and affect water taste.

Table 3: Area with turbidity, TDS, Ca, Mg, Cl above the permissible limit and below the desirable limit

Area	Turbidity NTU above the permissible/below the desirable limit	TDS mg/l above the permissible limit, below the desirable limit	Ca mg/l above the permissible limit/below the desirable limit	Mg mg/l above the permissible limit/below the desirable limit	Cl mg/l above the permissible limit /below the desirable limit
S1	8.9	-	-	-	137
S2	-	-	-	23	125
S3	-	-	-	-	199
S4	9.2	-	-	-	141
S5	-	-	-	22	133
S6	-	-	40	-	87
S7	0.8	-	62	-	46
S8	0.9	-	-	-	131
S9	0.5	412	54	-	50
S10	-	415	54	-	77
S11	-	-	-	-	185
S12	-	-	62	25	115
S13	0.4	-	-	27	187
S14	0.3	-	-	-	81
S15	-	-	45	-	75

Calcium

The groundwater samples showed calcium concentrations of 40-162 mg/L, which, while having no explicit BIS (IS 10500:2012) limit, translate to 100-405 mg/L as CaCO₃ hardness. Levels between 40-80 mg/L are nutritionally optimal, but higher concentrations (>100 mg/L) may cause scaling, reduce soap efficiency, and potentially increase kidney stone risk. These levels typically originate from natural sources like limestone dissolution and dolomite weathering (Table 1).

Iron

The study found iron concentrations of 0.2-2.0 mg/L in groundwater, with three sites (S1: 2.0 mg/L, S4: 1.8 mg/L,

S11: 1.0 mg/L) exceeding the BIS limit (0.3 mg/L) by 3-6 times. While not acutely toxic, chronic exposure may cause hemochromatosis, digestive issues, and nutrient absorption problems. Excessive iron also promotes bacterial growth, reduces disinfection efficiency, and causes staining/clogging of infrastructure. The reddish-brown discoloration confirms iron contamination, requiring remedial measures at affected sites (Ansari & Hemke, 2013, Table 2).

Magnesium

The groundwater contained magnesium concentrations of 22-85 mg/L (equivalent to 91-350 mg/L as CaCO₃ hardness), within BIS limits. While nutritionally beneficial at 24-60 mg/L, higher levels (>60 mg/L) may cause

temporary laxative effects and a bitter taste. These concentrations originate from the natural dissolution of dolomite and magnesium-rich minerals. Though compliant, values exceeding 70 mg/L warrant monitoring for potential scaling issues in water systems (Table 1).

Chloride

The study recorded chloride concentrations of 46-199 mg/L across all sampling sites, well below the permissible limit of 250-1000 mg/L (BIS standards). While anthropogenic sources like sewage leakage and waste dumping typically elevate chloride levels, the measured values indicate minimal contamination risk. Natural factors like soil porosity also contribute to chloride accumulation in groundwater, but current concentrations remain within safe drinking water parameters (Table 1).

Nitrate: The analyzed groundwater samples exhibited nitrate concentrations ranging from 5 mg/L to 15 mg/L. According to the Bureau of Indian Standards (BIS IS 10500:2012) for drinking water quality, the permissible limit for nitrate (as NO_3) is set at 45 mg/L, with no relaxation allowed. All measured values in this study were

well below this threshold, indicating compliance with national drinking water standards (Table 2).

Sulphate

Groundwater sulphates (18-40 mg/L) in all samples were well below BIS limits (200-400 mg/L), originating from natural mineral dissolution and potential industrial infiltration. While low levels indicate minimal hardness-contributing minerals, higher concentrations can affect water taste. The observed values reflect safe, naturally occurring sulphate levels per IS (Table 2).

Fluoride

The study found fluoride concentrations of 0.2-0.4 mg/L across all sites, below both BIS desirable (1.0 mg/L) and permissible (1.5 mg/L) limits. While optimal fluoride levels (1.0 mg/L) benefit dental health, the observed sub-optimal concentrations may increase fluorosis risk with long-term consumption as the primary intake source. Notably, excessive fluoride (>1.5 mg/L) causes dental/skeletal fluorosis, though current levels remain safe per IS:10500 standards. (Ansari and Hemke, 2013; Divya *et al.*, 2013) (Table 2).

Table 4: Area with Fe, NO_3 , SO_4 , F, As, E. coli above the permissible limit and below the desirable limit

Area	Fe mg/l above the permissible limit /below the desirable limit	NO_3 mg/l above the permissible limit/below the desirable limit	SO_4 mg/l above the permissible limit/below the desirable limit	F mg/l above the permissible limit/below the desirable limit	As above the permissible limit/below the desirable limit	E coli above the permissible limit/below the desirable limit
S1	2	10	40	0.2	BDL	Absent
S2	0.2	8	30	0.2	BDL	Absent
S3	0.3	10	30	0.2	BDL	Absent
S4	1.8	6	25	0.3	BDL	Absent
S5	0.2	8	26	0.2	BDL	Absent
S6	0.2	5	20	0.3	BDL	Absent
S7	0.2	8	20	0.3	BDL	Absent
S8	0.2	10	25	0.2	BDL	Absent
S9	0.3	15	18	0.4	BDL	Absent
S10	0.3	10	18	0.4	BDL	Absent
S11	1	5	20	0.3	BDL	Absent
S12	0.3	5	30	0.2	BDL	Absent
S13	0.3	10	25	0.3	BDL	Absent
S14	0.2	5	20	0.2	BDL	Absent
S15	0.8	5	20	0.2	BDL	Absent

Arsenic

As per the Bureau of Indian Standards (BIS 10500:2012) guidelines for drinking water quality, arsenic content in all tested groundwater samples was non-detectable, well within the acceptable limit of 0.01 mg/L (Table 2).

Total and Faecal Coliform

Total coliforms and faecal coliforms were absent in all sampled water sources, as confirmed by the Most Probable Number (MPN) method. Contaminated drinking water poses significant health risks, contributing to waterborne diseases

such as diarrhoea, cholera, hepatitis, schistosomiasis, guinea worm infection, trachoma, leishmaniasis, lymphatic filariasis, and malaria. Poor water quality and inadequate sanitation are key factors in the spread of these infectious diseases, which remain a major public health concern.

Coliform bacteria serve as critical indicators of water contamination. Their presence suggests potential pathogen contamination, rendering the water unsafe for consumption. High coliform levels, as observed in certain water samples, increase the likelihood of disease-causing bacteria being present (Table 2).

Table 5: Correlation matrix of thirteen parameters of water quality

	pH	Turb.NTU	EC	TDS mg/l	TH mg/l	Ca mg/l	Mg mg/l	Cl mg/l	Alkalinity mg/l	Fe mg/l	SO ₄ mg/l	NO ₃ mg/l	F mg/l
pH	1												
Turb. NTU	0.79	1											
EC	0.01	0.17	1										
TDS mg/l	0.01	0.18	1.00	1									
TH mg/l	0.21	0.36	0.37	0.36	1								
Ca mg/l	0.21	0.31	0.57	0.57	0.45	1							
Mg mg/l	-0.04	0.00	-0.23	-0.24	0.39	-0.65	1						
Cl mg/l	0.14	0.37	0.66	0.64	0.36	0.58	-0.25	1					
Alk	0.01	-0.11	0.75	0.73	0.20	0.32	-0.15	0.42	1				
Fe	0.54	0.88	0.19	0.22	0.17	0.20	-0.03	0.25	-0.17	1			
SO ₄	0.38	0.52	0.67	0.66	0.33	0.68	-0.40	0.50	0.58	0.44	1		
NO ₃	-0.30	-0.20	-0.09	-0.10	0.10	0.19	-0.10	-0.05	-0.20	-0.12	0.09	1	
F	-0.25	-0.22	-0.62	-0.61	-0.41	-0.43	0.09	-0.32	-0.71	-0.05	-0.61	0.40	1

Conclusion

Borehole water in Muzaffarpur City is the primary source of potable water. However, its contamination is exacerbated by unsustainable extraction rates and anthropogenic pollution, particularly through unregulated waste discharge into surface water systems. Evidence-based groundwater management strategies must be urgently formulated to reconcile urban development with environmental and public health preservation. Continued degradation of this critical resource will intensify regional water stress, potentially culminating in a socio-environmental crisis. Maintaining safe drinking water requires consistent quality checks and an effective operation and maintenance framework. Chlorine-based disinfectants or boiling water are strongly recommended before use.

Acknowledgements

The authors extend heartfelt thanks to the Regional Water Testing Laboratory, Muzaffarpur, for providing the necessary facilities and support to carry out this research.

Financial support

This research was self-funded.

Author contribution statement

BKPS: designed the experiment; NF: experimentation and manuscript writing; and BKPS: reviewed and edited the manuscript.

Conflicts of interest

No conflict of interest

References

1. Abhinav NS, Shankar P, Kumar R, Ali M, Verma SK, Ghosh AK, *et al.* Arsenic contamination of groundwater and human blood in Vaishali district of Bihar, India: health hazards. *Int J Adv Res.* 2017;5(8):2092–2100.
2. Ansari K, Hemke NM. Water quality index for assessment of water samples of different zones in Chandrapur City. *Int J Eng Res Afr.* 2013;3:233–237. doi:10.12691/ajwr-1-3-3.
3. Moussa A, Chandoul S, Mzali H, Salem S, Elmejri H, Zouari K, *et al.* Hydrogeochemistry and evaluation of groundwater suitability for irrigation purposes in the Mornag region, northeastern Tunisia. *Environ Dev Sustain.* 2020.
4. American Public Health Association. Standard methods for the examination of water and wastewater. 23rd ed. Washington (DC): APHA; 2017.
5. Azizullah A, Khattak MNK, Richter P, Häder DP. Water pollution in Pakistan and its impact on public health: a review. *Environ Int.* 2011;37(2):479–497.
6. Chakraborti D, Singh SK, Rahman MM, Dutta RN, Mukherjee SC, Pati S, *et al.* Groundwater arsenic contamination in the Ganga River Basin: a future health danger. *Int J Environ Res Public Health.* 2018;15(2):180. doi:10.3390/ijerph15020180.
7. Divya D, Barataria SK, Khanna PP. Ionic sources and water quality assessment around a reservoir in Tehri, Uttarakhand, Garhwal Himalaya. *Environ Earth Sci.* 2013;69:2513–2527. doi:10.1007/s12665-012-2076-2.
8. Lapworth DJ, Nkhuwa DCW, Okotto J, Pedley S, Stuart ME, Tijani MN, *et al.* Urban groundwater quality in sub-Saharan Africa: current status and implications for water security and public health. *Hydrogeol J.* 2012.
9. Eikelboom M, Wang Y, Portlock G, Gourain A, Gardner J, Bullen J, *et al.* Voltammetric determination of inorganic arsenic in mildly acidified (pH 4.7) groundwaters from Mexico and India. *Anal Chim Acta.* 2023;1246:341589. doi:10.1016/j.aca.341589.
10. Goon AM, Gupta MK, Dasgupta B. Fundamentals of statistics. Vol. I. Calcutta: World Press Pvt Ltd; 1986.
11. Pérez Villarreal J, Ávila Olivera JA, Israde Alcántara I, Buenrostro Delgado O. Nitrate as a parameter for differentiating groundwater flow systems in urban and agricultural areas: the case of Morelia–Capula area, Mexico. *Hydrogeol J.* 2019;27:1767–1778.
12. Kumar A, Ali M, Kumar R, Kumar M, Sagar P, Pandey RK, *et al.* Arsenic exposure in the Indo-Gangetic plains of Bihar is causing increased cancer risk. *Sci Rep.* 2021;11(1):2376. doi:10.1038/s41598-021-81579-9.
13. Kumar A, Kumar R, Rahman MS, Ali M, Nupur N, Gaurav A, *et al.* Assessment of arsenic exposure in the population of Sabalpur village of Saran district of Bihar with mitigation approach. *Environ Sci Pollut Res Int.* 2021. doi:10.1007/s11356-021-13521-5.
14. Kumar A, Rahman MS, Ali M, Kumar R, Niraj PK, Akhouri V, *et al.* Assessment of arsenic exposure and its mitigation intervention in the severely exposed population of Buxar district of Bihar, India. *Toxicol Environ Health Sci.* 2021. doi:10.1007/s13530-021-00086-6.
15. Kumar A, Ghosh AK. Assessment of arsenic contamination in groundwater and the affected population of Bihar. In: Kumar N, editor. Arsenic

- toxicity: challenges and solutions. Singapore: Springer; 2021. p. 123–145. doi:10.1007/978-981-33-6068-6_7.
16. Kumar A, Ali M, Kumar R, Rahman MS, Srivastava A, Chayal NK, *et al.* High arsenic concentration in blood samples of people of the village Gyaspur Mahaji, Patna, Bihar, who drink arsenic-contaminated water. *Exposure Health*. 2020;12:131–140.
 17. Kumar A, Ghosh AK. Arsenic and cancer. In: *Environmental exposures and human health challenges*. Hershey (PA): IGI Global; 2019. p. 106–132.
 18. Adimalla N, Qian H, Nandan MJ. Groundwater chemistry integrating the pollution index of groundwater and evaluation of potential human health risk: a case study from hard rock terrain of South India. *Ecotoxicol Environ Saf*. 2020;206:111217.
 19. Nickson RT, McArthur JM, Shrestha B. Arsenic and other drinking water quality issues, Muzaffargarh District, Pakistan. *Appl Geochem*. 2005;20(1):55–68. doi:10.1016/j.apgeochem.2004.06.004.
 20. Prasad M, Sunitha V, Sudharshan Reddy V, Suvarna B, Muralidhara Reddy B, Ramakrishna Reddy M. Data on water quality index development for groundwater quality assessment from Obulavaripalli Mandal, YSR district, Andhra Pradesh, India. *Data Brief*. 2019;24:103846. doi:10.1016/j.dib.2019.103846.
 21. Zhang Q, Sun J, Liu J, Huang G, Lu C, Zhang Y. Driving mechanism and sources of groundwater nitrate contamination in the rapidly urbanized region of South China. *J Contam Hydrol*. 2015;182:221–230.
 22. Richards LA, Kumar A, Shankar P, Gaurav A, Ghosh A, Polya DA. Distribution and geochemical controls of arsenic and uranium in groundwater-derived drinking water in Bihar, India. *Int J Environ Res Public Health*. 2020;17:9134–9152.
 23. Gao S, Li C, Jia C, Zhang H, Guan Q, Wu X, Wang J. Health risk assessment of groundwater nitrate contamination: a case study of a typical karst hydrogeological unit in East China. *Environ Sci Pollut Res*. 2020;27(9):9274–9287.
 24. Abhinav A, Navin S, Kumar A, Kumar R, Ali M, Verma SK, *et al.* Prevalence of high arsenic concentration in Darbhanga district of Bihar: health assessment. *J Environ Anal Toxicol*. 2016;6(410):1–6.
 25. Verma P, Singh PK, Sinha RR, Tiwari AK. Assessment of groundwater quality status by using water quality index and geographic information system approaches: a case study of the Bokaro district, India. *Appl Water Sci*. 2020;10:119–128.
 26. Shi XY, Wang Y, Jiao JJ, Zhong JL, Wen HG, Dong R. Assessing major factors affecting shallow groundwater geochemical evolution in a highly urbanized coastal area of Shenzhen City, China. *J Geochem Explor*. 2018;184:17–27.