

Pre-Monsoon Groundwater Quality and Suitability for Drinking in Kahalgaon, Bihar: Physico-Chemical Parameters, Heavy Metals and Water Quality Index

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Abstract:

Water and its quality are essential for the survival of human beings. Water is necessary for agriculture, drinking, industrial and several other purposes. Due to certain anthropogenic activities, the groundwater quality in the sub-division of Kahalgaon of Bhagalpur district in Bihar, India, has deteriorated. This paper focuses on the water quality analysis of the region with respect to physico-chemical parameters. The samples have also been analyzed for the presence of some heavy metals. Parameters such as pH, TDS, salinity and electrical conductivity were tested on site. Testing for alkalinity and hardness was done as per the CPCB Water and Waste Water Manual. Further, an Atomic Absorption Spectrophotometer (AAS) was used for the analysis of arsenic, chromium, lead and zinc, which were below the detection limit in all samples. The analyzed results have been compared with the Indian Standard drinking water specifications (IS 10500:2012). A total of 28 samples were collected from tube wells and open wells of the area. The pH of all but one sample was within the acceptable limit. The average concentrations of TDS, total hardness, alkalinity (as CaCO_3) and salinity are 762 mg/L, 213 mg/L, 361 mg/L and 565 mg/L respectively, and the average TDS, hardness and alkalinity exceed the acceptable limits, with only 21% and 7% of the samples complying for TDS and alkalinity respectively. The Water Quality Index (WQI) has also been calculated, which indicates that 54% of the samples collected have good quality water and 43% have poor quality water. Only one location, Daulatpur, had excellent water quality, and no sample was very poor or unsuitable for drinking as per the WQI classification.

Keyword: Groundwater quality, Water Quality Index (WQI), Physico-chemical parameters, Heavy metals, Kahalgaon, Bhagalpur, Bihar, IS 10500:2012

1. Introduction

Water is one of the most important resources for the survival of living beings on earth. Depending on its characteristics, it is used for agriculture, domestic purposes, industry and, most importantly, drinking. Over-exploitation of groundwater for these purposes has created a serious problem of water scarcity and declining quality. In many parts of the country the water table has been reported to fall at the rate of about 1 m/year, and water quality is also deteriorating at an alarming rate [1]. Groundwater is especially important in India, where a large share of the rural population depends on it for drinking and domestic

use, and it is also widely used for irrigation [2]. Because groundwater is usually assumed to be cleaner than surface water, it is often consumed with little or no treatment, so any decline in its quality is a direct public health concern. It is therefore essential to have clean water in sufficient quantity.

The quality of groundwater is shaped by natural factors such as geology, aquifer mineralogy, recharge and water-rock interaction, and by human activities. Excessive extraction, agricultural runoff containing fertilizers and pesticides, untreated domestic sewage, industrial effluents and poor waste disposal can all alter its chemical composition [3]. High concentrations of dissolved solids, hardness and alkalinity affect taste and suitability for domestic use, while trace metals and metalloids such as arsenic, chromium and lead can cause serious long-term health effects even at low concentrations [4], [5].

The middle Ganga plain of Bihar has been widely reported to have arsenic-contaminated groundwater, and several districts along the river have shown concentrations above the permissible limit [6]. Bhagalpur district lies in this region, and the Kahalgaon sub-division, situated on the Ganga, is affected by agricultural activity, rapid settlement growth and industrial development, including a large thermal power station. Despite this, systematic information on the physico-chemical quality of groundwater in the sub-division is limited, and residents rely largely on tube wells and open wells for their daily water needs.

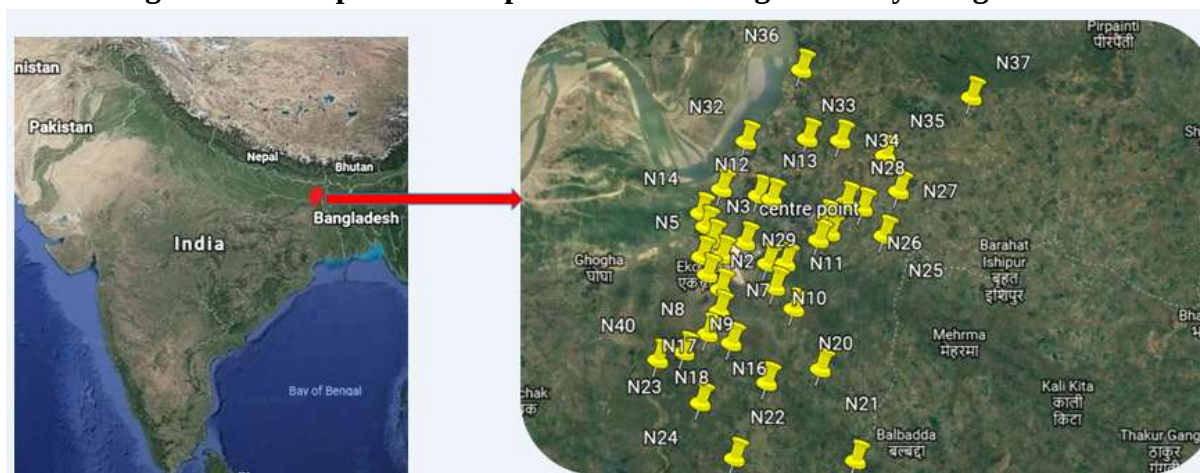
The quality of water can be ascertained using physical, chemical and biological parameters, each of which may affect water quality in its own way. The Indian Standard Drinking Water Specification (IS 10500) of the Bureau of Indian Standards prescribes desirable and permissible limits for these parameters [7], and the World Health Organization provides corresponding international guideline values [8]. However, to obtain a holistic idea of the purity of water with respect to its potability, the Water Quality Index (WQI) is used [9], [10]. The WQI is a rating that reflects the composite influence of different water quality parameters on the overall quality of water, and it classifies water from excellent to unfit for drinking. The Indian standard specified for drinking water is used as the basis for its calculation [11].

The present study therefore evaluates the groundwater quality of the Kahalgaon sub-division of Bhagalpur district, Bihar. Twenty-eight samples were collected from tube wells and open wells and analyzed for pH, total dissolved solids (TDS), salinity, electrical conductivity, alkalinity and total hardness, using on-site measurements and standard laboratory procedures [12], [13]. Arsenic, chromium, lead and zinc were determined using an Atomic Absorption Spectrophotometer (AAS). The results were compared with the Indian drinking water standards, and the WQI was calculated to classify the suitability of water at each sampling location. The findings aim to provide baseline data to support the management and protection of groundwater in the region.

2. Study Area

The Bhagalpur district is located in the south-eastern part of the state of Bihar. It extends between north latitudes 25°03'40" and 25°30'00" and east longitudes 86°30'00" and 87°29'45", and falls in Survey of India toposheet nos. 72 K and O. The district has sixteen community development blocks, of which Kahalgaon is one. Kahalgaon lies on the eastern side of the district. The major water-bearing formation is alluvium. The predominant geological formations are Quaternary deposits and the Precambrian basement of granitic gneiss, with a few exposures as inliers [14].

Fig-1: Location point of sample collection. Image courtesy Google Earth



Kahalgaon is situated on the bank of the river Ganga. The land is fertile and suitable for agriculture. The silk industry is one of the major industries of the area, and silk is an exportable item. There is also a growing trend towards computer-based service enterprises, mineral water plants, garment industries and food-based industries [15]. NTPC has established a super thermal power plant at Kahalgaon. Water analysis was carried out in the areas near the ash pond of the power plant. An area within an approximate radius of 10 km from the ash pond was considered, and 28 samples were collected from tube wells and open wells.

3. Methodology

3.1 Sample Collection

The field work involved the collection of groundwater samples from the region around the NTPC Super Thermal Power Plant, Kahalgaon, within a radius of about 10 km from the ash pond. A total of 28 samples were collected from tube wells and open wells, during the pre-monsoon period. Water levels in the region varied from 20 to 200 feet, as reported by local residents. The samples were collected after 5 minutes of pumping and stored in properly washed polyethylene bottles. All samples were analysed within 4 days of collection. No chemical preservative was added, as the samples were analysed within 4 days of collection. They were kept in tightly closed polyethylene bottles and stored away from direct sunlight until analysis. The delay between sampling and analysis may have caused minor changes in some parameters, particularly alkalinity, pH and metal concentrations, which is a limitation of this study.

3.2 Analytical Methods

A T200 Digital TDS Meter was used to measure the in-situ parameters: electrical conductivity, TDS, salinity, pH and temperature. The samples were tested for alkalinity, total hardness, calcium hardness, magnesium hardness and the metal ions zinc, lead, chromium and arsenic. The test methods followed were the standard procedures recommended by the Central Pollution Control Board [12]. The metal ions were analysed using an Atomic Absorption Spectrophotometer (AAS).

3.3 Data Analysis

Descriptive statistics (Mean, Standard Error, Median, Mode, Standard Deviation, Sample Variance, Kurtosis, Skewness, Range, Minimum, Maximum, Sum and Count) were calculated for all parameters. The results were compared with the Indian Standard for drinking water (IS 10500:2012) to determine the percentage of samples complying with the acceptable limit for each parameter, calculated as the number

of samples within the limit divided by the total number of samples ($n = 28$), multiplied by 100. All statistical analyses were carried out using MS Excel.

3.4 Water Quality Index

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To obtain a comprehensive picture of the overall quality of the groundwater, the Water Quality Index (WQI) was calculated. The WQI is a rating that reflects the composite influence of different water quality parameters on the overall quality of water [10], [11]. It was computed by the weighted arithmetic index method [11], [16], using the desirable limits of the Indian standard for drinking water, IS 10500:2012 [7], in the following steps.

Step 1: Assignment of weights. Six parameters (pH, total hardness, calcium, magnesium, alkalinity and TDS) were each assigned a weight (w_i) on a scale of 1 to 5 according to their relative importance in the overall quality of water for drinking purposes [11], [16]. pH and TDS were assigned a weight of 4, alkalinity a weight of 3, and total hardness, calcium and magnesium a weight of 2, giving $\sum w_i = 17$. Heavy metals (arsenic, chromium, lead and zinc) were excluded from the index because their concentrations in all samples were below the detection limit [state the detection limits].

Step 2: Relative weights. The relative weight (W_i) of each parameter was calculated as:

$$W_i = w_i / \sum w_i$$

Step 3: Quality rating and sub-index. The quality rating (q_i) of each parameter was calculated by dividing its concentration in each water sample by the corresponding standard and multiplying by 100:

$$q_i = (C_i / S_i) \times 100$$

where C_i is the concentration of the parameter in the sample and S_i is its desirable limit in IS 10500:2012 [7]. The standard values used were 6.5–8.5 for pH, 500 mg/L for TDS, 200 mg/L for total hardness (as CaCO_3), 75 mg/L for calcium, 30 mg/L for magnesium and 200 mg/L for alkalinity (as CaCO_3). The sub-index (SI_i) of each parameter and the overall WQI were then obtained as:

$$SI_i = W_i \times q_i$$

$$WQI = \sum SI_i$$

where SI_i is the sub-index of the i^{th} parameter and q_i is the rating based on its concentration. The WQI values were classified into five categories, as shown in Table 3 [10], [16].

Table 1. Water quality index and its classification

WQI	Classification
< 50	Excellent quality
50–100	Good quality
100–200	Poor quality
200–300	Very poor quality
> 300	Unsuitable for drinking

4. Results and Discussion

4.1. Descriptive Statistics

Table 2. Descriptive Statistics of 28 water samples taken from different locations

	TH	Ca	Mg	Alk.	pH	EC	Sal.	TDS	T
	mg/L	mg/L	mg/L	mg/L		$\mu\text{S/cm}$	mg/L	mg/L	C
Mean	213.01	31.05	31.41	361.27	6.97	1132.50	565.07	762.14	30.03

Standard Error	15.83	2.38	2.40	20.76	0.06	99.38	49.17	69.08	0.37
Median	204.59	29.38	30.20	360.85	6.92	1160.00	574.50	768.50	29.35
Mode	207.50	#N/A	#N/A	390.83	6.90	1170.00	#N/A	#N/A	28.50
Standard Deviation	83.75	12.62	12.68	109.85	0.33	525.89	260.17	365.53	1.97
Sample Variance	7014.67	159.23	160.82	12067.52	0.11	276562.70	67690.14	133611.02	3.86
Kurtosis	0.82	0.83	0.82	0.52	21.95	-1.01	-1.03	-0.89	-0.92
Skewness	0.83	0.84	0.83	-0.17	4.45	-0.14	-0.14	0.04	0.37
Range	342.72	51.74	51.94	480.83	1.87	1717.00	861.00	1275.00	7.10
Minimum	78.33	10.75	10.94	100.00	6.72	260.00	128.00	174.00	26.50
Maximum	421.05	62.49	62.88	580.83	8.59	1977.00	989.00	1449.00	33.60
Sum	5964.40	869.33	879.58	10115.52	195.26	31710.00	15822.00	21340.00	840.80
Count	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00

The descriptive statistics are given in Table 2. Mean TDS (762 mg/L), alkalinity (361 mg/L as CaCO₃) and total hardness (213 mg/L) exceed their desirable limits in IS 10500:2012, although all samples remain below the permissible limits. The pH of one sample (8.59) slightly exceeded the upper limit of 8.5, and the high coefficients of variation (30-48%) for TDS, EC, hardness and alkalinity indicate strong spatial variability in groundwater chemistry. Arsenic, chromium, lead and zinc were below the detection limit in all samples. Because the pH is mostly below 8.3, the alkalinity is attributed mainly to bicarbonate from carbonate and silicate weathering in the alluvial aquifer, while the elevated TDS may also reflect agricultural and domestic inputs and possible leaching from the nearby ash pond.

4.2 Compliance with IS 10500:2012

Table 3. Percentage of Samples Complied with Acceptable limit as per IS 10500:2012

Parameter	Unit	IS 10500:2012 Acceptable limit	No. of Samples within Acceptable Limit	%age of Samples within Acceptable Limit
Total Hardness	mg/L	200	12	42.86
Calcium	mg/L	75	75	100.00
Magnesium	mg/L	30	14	50.00
Alkalinity	mg/L	200	2	7.14
pH		6.5 to 8.5	27	96.43
TDS	mg/L	500	6	21.43

The percentage compliance of the samples with the acceptable limits of IS 10500:2012 is given in Table 3. Alkalinity (7.14%) and TDS (21.43%) showed the lowest compliance, with 26 and 22 of the 28 samples exceeding the acceptable limit, respectively. Total hardness (42.86%) and magnesium (50%) were exceeded in 16 and 14 samples, whereas calcium (100%) and pH (96.43%) were largely within limits, with only one sample exceeding the upper pH limit. Although many samples exceeded the acceptable limits, the maximum values of TDS, hardness, alkalinity and magnesium were all below their permissible limits, so the water may be used in the absence of an alternate source. The widespread exceedance of alkalinity and TDS points to carbonate-dominated mineralisation and high dissolved ion content in the aquifer, which can affect taste and cause scaling, and these two parameters will largely control the quality index.

4.3 Water Quality Index

Table 4: Water Quality Index of different Sample Location and its Classification

Sample No	Latitude	Longitude	Location Name	WQI	Classification
N1	25.211944	87.211687	BHOLSAR	110.52	Poor Quality
N2	25.212335	87.222262	PURABTOLA,EKCHARI	126.47	Poor Quality
N3	25.204064	87.2163	RASALPUR(MAA DURGA STHAN)	87.55	Good Quality
N4	25.195321	87.221782	RASALPUR(HANUMAN MANDIR)	65.00	Good Quality
N5	25.209167	87.245833	DHANAURA	98.55	Good Quality
N6	25.196121	87.241821	MASDOHA	128.98	Poor Quality
N7	25.239307	87.254632	OGRI	93.61	Good Quality
N8	25.238363	87.248083	SHARAFUDDINPUR	130.35	Poor Quality
N9	25.231416	87.214245	TRIMUHAN	79.57	Good Quality
N10	25.24191	87.220747	PAKARTALLA	103.62	Poor Quality
N11	25.176713	87.217144	GOKULPUR	69.99	Good Quality
N12	25.184742	87.220629	RAMPUR KHARAHARA	91.76	Good Quality
N13	25.172819	87.227124	MADARGANJ	123.08	Poor Quality
N14	25.197	87.249444	DHANAURA(CHAITI DURGA MANDIR)	93.58	Good Quality
N15	25.188582	87.260332	DHANAURA(MAA DURGA STHAN)	91.50	Good Quality
N16	25.159424	87.273076	SANOKHAR	104.97	Poor Quality
N17	25.244425	87.315017	MAHESHKHAR	98.45	Good Quality
N18	25.167346	87.202143	GATHAUR	69.15	Good Quality
N19	25.220178	87.181201	DAULATPUR	40.09	Excellent
N20	25.273955	87.27229	BANSIPUR	124.70	Poor Quality
N21	25.239631	87.271874	SOBHNATHPUR	156.25	Poor Quality
N22	25.265428	87.233336	KAHALGAON(NATIONAL HIGHWAY 80)	99.84	Good Quality
N23	25.267907	87.258797	JAN MAHAMMADPUR	94.23	Good Quality

N24	25.256098	87.288977	SALEMPUR	104.54	Poor Quality
N25	25.165417	87.19085	FARIDAMPUR	55.23	Good Quality
C	25.219444	87.232778	ASH POND	108.81	Poor Quality
R1	25.218713	87.165874	KULKULIYA GHOGHA	76.05	Good Quality
R2	25.214644	87.169655	SHAHPUR GHOGHA	175.26	Poor Quality

5. Conclusion

The WQI values ranged from 40.1 to 175.3 (mean 100.1) (Table 4). One sample (Daulatpur) was of excellent quality, 15 (53.6%) were good and 12 (42.9%) were poor, and none was very poor or unsuitable for drinking. The poorest quality occurred at Shahpur Ghogha (175.3), Sobhnathpur (156.3) and Sharafuddinpur (130.4). The poor class is mainly due to TDS and alkalinity, which exceeded the acceptable limits in 79% and 93% of the samples and carry high weights in the index. The ash pond sample (108.8) was poor, but nearby locations such as Dhanaura were good, so no clear ash-pond influence is evident and the variation appears to be local.

The groundwater quality of the Kahalgau sub-division of Bhagalpur district was assessed using 28 samples collected from tube wells and open wells in the pre-monsoon season. The mean values of TDS (762 mg/L), alkalinity (361 mg/L as CaCO₃) and total hardness (213 mg/L) exceeded the acceptable limits of IS 10500:2012, with only 21%, 7% and 43% of the samples complying, respectively. All samples remained below the permissible limits, and all but one sample were within the pH limit. Arsenic, chromium, lead and zinc were below the detection limit in all samples.

The Water Quality Index showed that 54% of the samples were of good quality and 43% were of poor quality. Only one location (Daulatpur) was of excellent quality, and no sample was very poor or unsuitable for drinking. The poor quality was mainly due to high TDS and alkalinity, and the variation in WQI between nearby locations, including those near the ash pond, indicates strong local variability rather than a clear spatial pattern.

The water of the study area can therefore be used for drinking in the absence of an alternate source, but the poor-quality locations, such as Shahpur Ghogha, Sobhnathpur and Sharafuddinpur, should be treated before use. Regular monitoring, including post-monsoon sampling and metal analysis with low detection limits, is recommended to follow seasonal changes and confirm the absence of toxic metals.

6. References

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