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Groundwater Quality Assessment and Evaluation of Scaling and Corrosiveness Potential of Drinking Water Samples †

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Abstract: This research was to examine water stability and to evaluate the drinking water quality. Groundwater samples from 16 borewells in Aurangabad, Bihar, were taken from the shallow unconfined aquifer and tested for a wide range of physicochemical characteristics. The pH, temperature, TDS, and EC were measured at the sites. Ca^{2+}, Mg^{2+}, F^-, Cl^-, $NO_3{}^-$, $SO_4{}^{2-}$, alkalinity, and hardness concentrations were examined in the laboratory. The groundwater's stability was measured using Corrosiveness Indices including the Langeliar saturation index (LSI), Ryznar stability index (RSI), Puckorius scaling index (PSI), Larson-Skold index (Ls), and Aggressivity index (AI). The data showed that typical values for LSI, RSI, PSI, and LS and AI were −0.92 (±0.47), 9.09 (±0.67), 9.50 (±0.73), 1.73 (±0.78), and 11.05 (±0.48), respectively. Groundwater WQI calculations revealed that 25% of the samples were excellent, 50% were good, 19% were poor, and 6% were extremely poor. All of the water samples tested positively for corrosiveness according to the LSI and PSI indices. Water samples show a strong corrosive potential (87.50% according to RSI) or a low corrosive tendency (12.50% according to RSI). 75% of the water samples have a strong corrosive tendency, 18.50% have a corrosive tendency, and 6.25% have a scaling tendency, according to Ls. According to AI, 93.75% of the water samples had a moderately corrosive tendency, whereas 6.25% were extremely corrosive.

Keywords: groundwater quality; water qk ality index (WQI); statistical analysis; scaling and corrosiveness potential

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1. Introduction

Water is essential for human survival. However, not all the water available in our system may be suitable for human consumption [1]. Population growth has resulted in a massive increase in groundwater demand [2]. Groundwater is an essential source for domestic and industrial purposes [3]. The overuse of groundwater, resulting in the depletion of the groundwater table and the deterioration of groundwater quality as a result of human activities has serious socioeconomic consequences [4]. Among the most effective tools and important parameters for the evaluation and management of groundwater quality, the WQI method is widely used around the world for groundwater quality assessment. WQI is a reflection and ranking of water quality based on the combined effects of different variables [5]. The organic nature of water is affected by corrosion-based physicochemical reactions. Water corrosion and scaling can be predicted with analytical terminology such as Ryznar stability index (RSI), Aggressive index (AI), Langelier saturation index (LSI), Larson-Skold index (LS), and Puckorius scaling index (PSI) [6,7]. The primary goals of this study are to assess the groundwater quality and corrosive potential of drinking water samples. Which help in managing future sustainable groundwater management approaches in the Aurangabad District, Bihar.

2. Study Area

The state of Bihar has a central position in the Gangetic Plain of India. South Bihar Plains (SBP) is a part of the Ganga Basin's periphery alluvial plains, and the region depicted in Figure 1 is its research area, which spans 3389 km^2 between longitudes 84°00′–84°45′ E and latitudes 24°30′–25°15′ N.

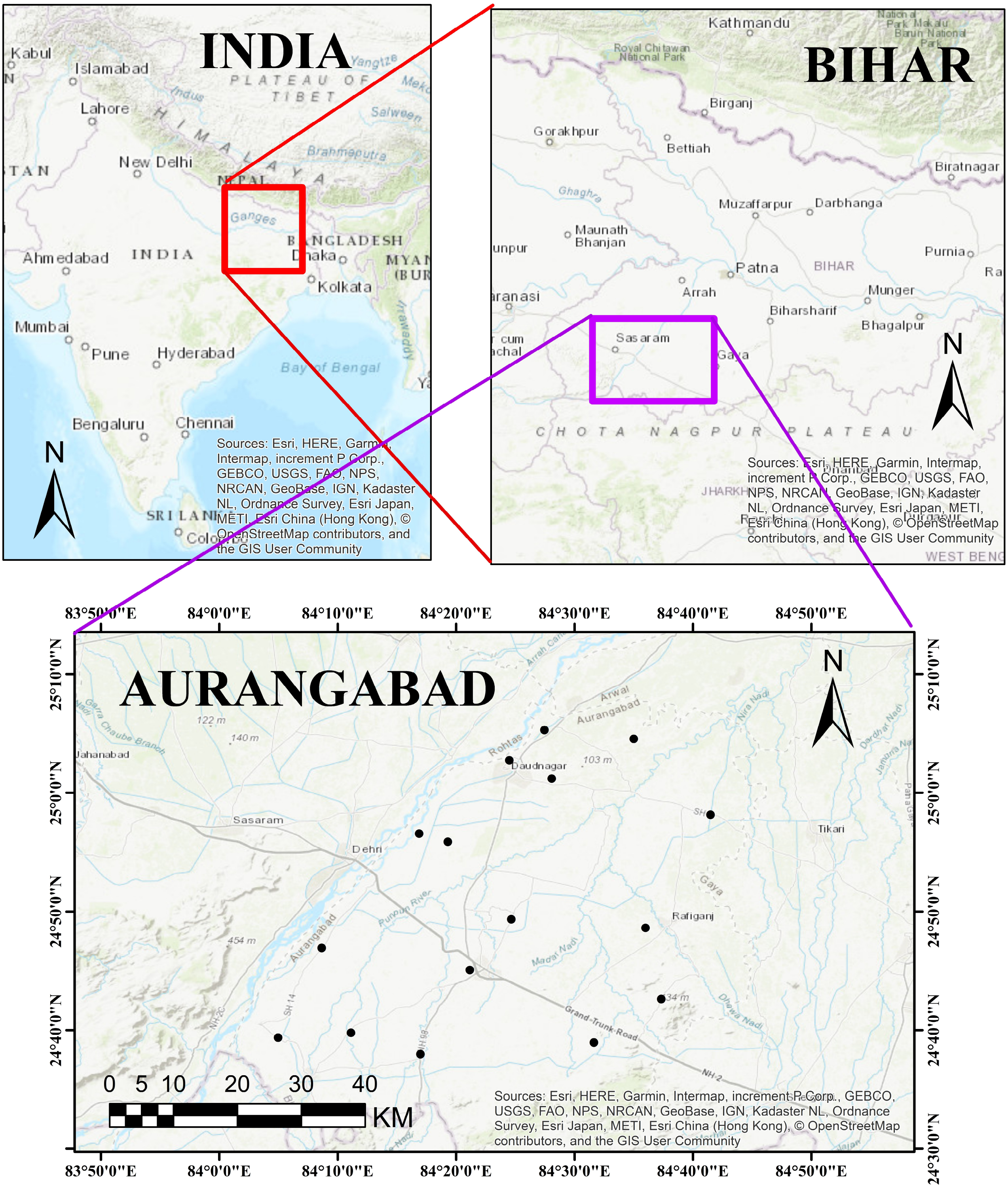

Figure 1. Map of study area.

3. Materials and Methods

3.1. Sampling and Data Analysis

There were 16 samples of groundwater taken from the study area using borewells or hand pumps. The sites were located using GPS. Pre-cleaned 1 L high density PVC bottles were used to collect water samples. Samples were taken for physicochemical analysis using standard methods [8]. A Thermo Scientific Multi-Parameters Kit was used at the site to measure the pH, EC, temperature, and TDS. The concentrations of chloride, sulphate, and phosphate were determined in the laboratory using $AgNO_3$ titration method, turbidimetric method, and colorimetric method, respectively. The standard EDTA method was used to determine total hardness, calcium hard-ness, and magnesium hardness. The dissolved oxygen concentration was determined using Winkler's modified method.

3.2. Determination of Water Quality Index

Water Quality Index was developed by Horton to assess the quality of groundwater [9]. WQI is a rating that assesses the impact of several parameters on water quality. For the calculation of WQI, all stages were performed as described by [10].

3.3. Determination of Corrosiveness Indices

LSI, RSI, PSI, Ls, and AI were used to assess the corrosion potential of water samples. There were seven physicochemical parameters that were used in calculating these indices: pH, temperature, TDS, alkalinity, calcium hardness, chloride, sulphate. As shown in Table 1, corrosiveness indices have been calculated.

Table 1. Equations and classification of Corrosiveness indices.

Index	Equation	Index Value	Tendency of Water
Langelier saturation index (LSI)	$LSI = pH - pHs$ $pHs = (9.3 + A + B) - (C + D)$ $A = (\log(TDS) - 1)/10$ $B = -13.2(\log(°C + 273)) + 34.55$ $C = \log(Ca^{++} \text{ as } CaCO_3) - 0.4$ $D = \log(\text{Alkalinity as } CaCO_3)$	LSI < 0 LSI = 0 LSI > 0	Corrosive tendency Neutral tendency Scaling tendency
Ryznar stability index (RSI)	$RSI = 2pHs - pH$	RSI < 5.5 5.5 < RSI < 6.2 6.2 < RSI < 6.8 6.8 < RSI < 8.5 RSI > 8.5	High Scaling tendency Scaling tendency Neutral tendency Low corrosive tendency High Corrosive tendency
Puckorius scaling Index (PSI)	$PSI = 2pHs - pHeq$ $pHeq = 1.465\log(\text{Alkalinity}) + 4.54$ $\text{Alkalinity} = HCO_3^- + 2(CO_3^-) + OH^-$	PSI > 7 PSI < 6	Corrosive tendency Scaling tendency
Larson-Skold Index (Ls)	$Ls = (C_{Cl^-} + C_{SO_4^{2-}})/(C_{HCO_3^-} + C_{CO_3^{2-}})$ C = Concentration in mg/L	Ls > 1.2 0.8 < Ls < 1.2 Ls < 0.8	High corrosive tendency Corrosive tendency Scaling tendency
Aggressive index (AI)	$AI = pH + \log((Ca^{++}) \times (\text{Alkalinity}))$	AI < 10 10 < AI < 12 AI > 12	Corrosive tendency Moderately Corrosive Scaling tendency

4. Results and Discussion

4.1. Physicochemical Analysis

Statistical analyses of the groundwater samples are presented in Table 2, along with the consequences of elements above the limit for use in drinking water. The water quality parameters such as pH, Cl^-, NO_3^-, SO_4^{2-} were found to be well below the [11] acceptable limit. The parameters like TDS, F, TH and Ca exceed the acceptable limits of the (WHO, 2006 [11]).

Table 2. Statistical analysis results on the study area groundwater data.

	pH	TDS (mg/L)	EC (µS/cm)	DO (mg/L)	F^- (mg/L)	Cl^- (mg/L)	NO_3^- (mg/L)	SO_4^{2-} (mg/L	Alk. (mg/L)	TH (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)
Min	6.67	139.0	242.5	1.15	0.10	16.81	2.791	3.85	14.66	133.5	82.89	36.84
1st Qu.	7.06	287.0	530.3	1.71	0.52	33.02	11.45	9.38	34.65	201.5	139.30	54.11
Median	7.24	340.2	645.0	2.05	0.71	40.13	18.64	15.78	39.24	276.3	161.18	101.31
Mean	7.26	369.8	721.8	2.02	0.90	51.55	21.63	15.28	39.91	298.7	176.43	122.32
3rd Qu.	7.53	387.9	771.9	2.24	1.11	63.72	31.06	18.48	47.34	351.1	184.20	174.99
Max.	7.84	839.0	1669.0	2.89	2.20	169.28	49.34	38.69	58.81	704.6	492.74	290.12
WHO	7–8	600	-	-	1.5	250	50	250	-	200	100	-

4.2. Water Quality Analysis

In 16 water samples, 25% of the water samples fell in the excellent water quality, 50% of the water sample in good water quality, 19% of water samples are poor and 6% of samples are not suitable for drinking (Figure 2). In the groundwater samples, the WQI values ranged from 33.97 to 201.43 (Figure 3f). A majority of the study area has groundwater of consumable quality and that can be used for drinking as well as domestic purposes.

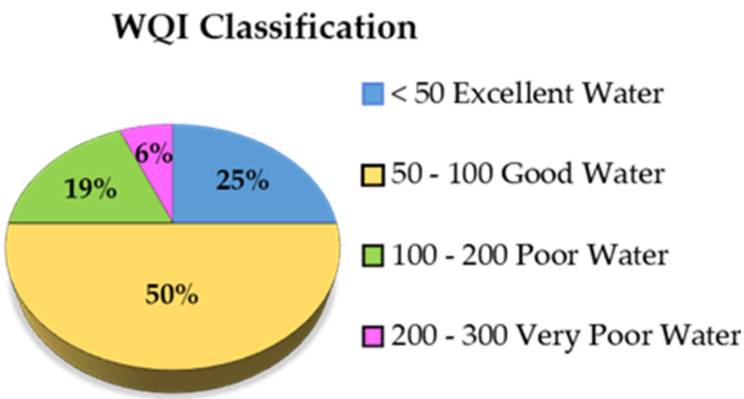

Figure 2. Water quality classification based on WQI value.

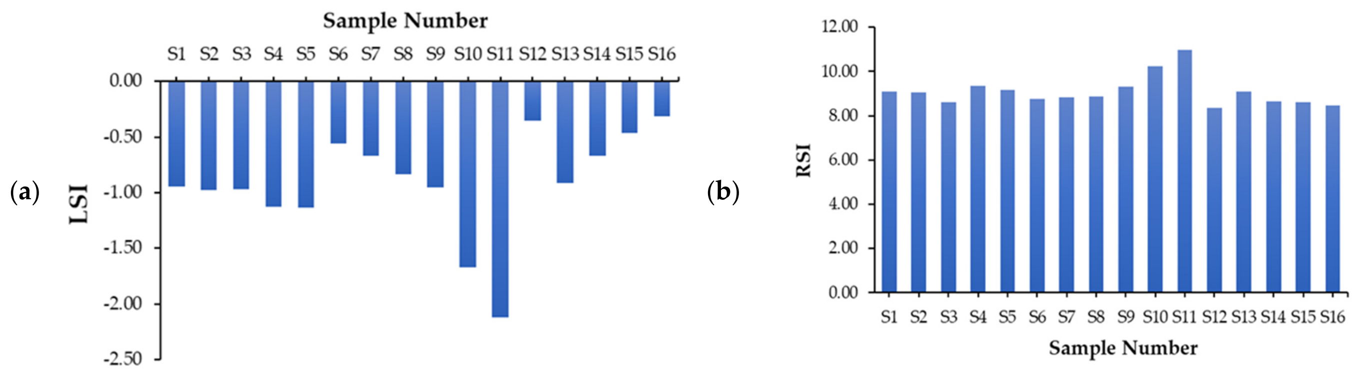

Figure 3. *Cont.*

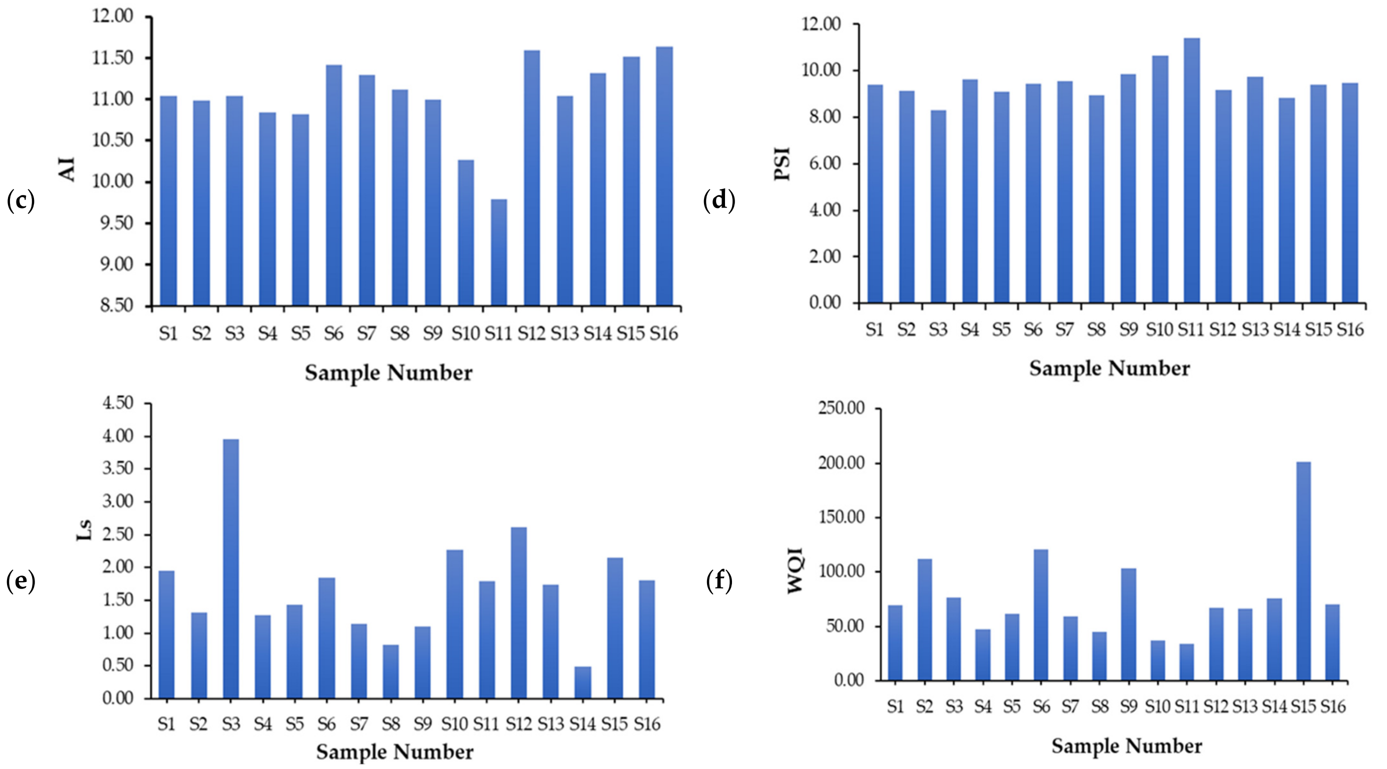

Figure 3. Corrosiveness indices (**a**) LSI, (**b**) RSI, (**c**) AI, (**d**) PSI, (**e**) Ls, and (**f**) WQI of the water samples.

4.3. Corrosiveness Potential of Water Samples

The descriptive study of the corrosiveness indices is shown in Table 3.

Table 3. Descriptive statistics of the Corrosiveness Indices.

Corrosiveness Indices	Minimum	Maximum	Mean ± Standard Deviation
LSI	−2.12	−0.31	−0.92 ± 0.47
RSI	8.36	10.96	9.09 ± 0.67
AI	9.79	11.64	11.05 ± 0.48
PSI	8.29	11.42	9.50 ± 0.73
L_S	0.49	3.95	1.73 ± 0.78

4.3.1. Langelier Saturation Index (LSI)

The LSI includes a valuable indicator for detecting corrosive water. As defined by [12], LSI is the difference between the measured pH and the saturated pH. A negative average LSI value of −0.92 indicates corrosive tendencies in the water samples shown in Table 3. Figure 3a illustrates that all water samples exhibit corrosive characteristics.

4.3.2. Ryznar Stability Index (RSI)

Ref. [13] defines RSI as the difference between the double of saturation pH and the pH of the actual water. The average value of RSI was found to be 9.09, which indicates a high tendency toward corrosion. S12 and S16 had a low corrosive tendency, whereas the rest of the samples had a high corrosive tendency (Figure 3b).

4.3.3. Puckorius Scaling Index (PSI)

The PSI predicts the ultimate amount of sediment by examining the buffering capacity of the water and the amount of precipitation that will occur when the water reaches equilibrium [14]. It fell into the corrosive tendency with an average PSI of 9.50. All samples have a corrosive tendency, as shown in Figure 3c.

4.3.4. Larson-Skold Index (Ls)

Based on the concentration of chloride, sulphate, carbonate and bicarbonate alkalinity the mathematical equation for Ls is derived [15]. There was an average Ls of 1.73, which indicates highly corrosive water. Figure 3d shows that S7, S8, S9 fell into the corrosive tendency, while S14 fell into the scaling tendency, otherwise they fell into the high corrosive tendency.

4.3.5. Aggressive Index (AI)

A formula for AI is calculated by incorporating parameters such as calcium hardness (Ca), pH and total alkalinity [16]. The average AI value was 11.05, indicating a moderate corrosive tendency. Figure 3e depicts that sample S11 has corrosive tendencies, whereas the rest are moderately corrosive.

5. Conclusions

In this study, WQI of groundwater samples revealed that 75% had excellent or good water, and 25% either had poor or very poor water. This study also evaluated the scaling and corrosion potential of drinking water samples. Mainly, iron and steel pipes were used to extract groundwater. LSI and RSI are the main indicators that are utilized for corrosion monitoring in iron and steel pipes. LSI indicates that all water samples had a corrosive tendency, and RSI indicates 87.5% high corrosive tendency. These indices are based on pH, temperature, TDS, Ca^{++}, and alkalinity, all of which have a significant impact on water quality. Chloride and sulfate ions corrode iron and steel pipes and degrade water quality. Ls is also a good tool for monitoring corrosion in iron and steel pipes. In water samples, Ls indicates a 75% high corrosive tendency, an 18.75% corrosive tendency, and a 6.25% scaling tendency. All these indices indicate that water has a corrosive tendency, which can degrade materials and affect water quality. Therefore, the study area regularly monitors groundwater quality for sustainability. Pipe material should be used according to the analysed parameters. So that the lifespan of the pipe may increase while the quality of the water remains unchanged.

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