AATCC Review

04 November 2024: Received
29 January 2025: Revised
20 February 2025: Accepted
22 February 2025: Available Online

https://aatcc.peerjournals.net/

Original Research Article

Open Access

Assessment of Water Hydrochemistry and Its Suitability for Drinking and Irrigation inThakurganj Block, Kishanganj, Bihar

D. K. Verma[1], S. K. Dutta[2], B. K. Vimal[1], Nintu Mandal[1], Vimal Kumar[1*], Chandrabhan Patel[1] and A. K. Singh[3]

[1]*Department of Soil Science and Agricultural Chemistry, BAU, Sabour, Bihar, India*
[2]*Department of Agronomy. BAU, Sabour, Bihar,India*
[3]*Director Research, BAU, Sabour, Bihar, India*

ABSTRACT

Groundwater contamination is a major environmental concern that impacts both irrigation and drinking water supplies. To evaluate the water quality in Thakurganj block, Kishanganj district, Bihar, for its suitability for drinking and irrigation, a total of 55 groundwater samples (1000 mL each) were collected using GPS-based methods between April and May 2022. The samples were stored in plastic bottles at 4°C for laboratory analysis of their physicochemical properties. Standard methodologies were used for analysis, and the results were assessed based on the guidelines of WHO, APHA and USDA for drinking and irrigation purposes. Many groundwater samples from the Thakurganj block were found unsuitable for drinking due to high iron contamination, exceeding the permissible limit. However, the groundwater was classified under the C1S1 category for irrigation, indicating it is suitable for crop production.

Keywords: *Groundwater, Drinking Water Quality, Irrigation Water Quality.*

Introduction

Groundwater in the Thakurganj block of Kishanganj district is the primary source for drinking and irrigation use. The water table in these areas was found to be up to 20.0 feet below the surface. While groundwater is available in sufficient quantities, some parts or patches suffer from poor water quality, making it unsuitable for drinking. The purity of ground-water is recently as important as its quantity, depending on its suitability for various uses. Recent years have seen a decline in water quality due to factors like intensive agriculture, domestic and industrial discharge, over-exploitation, irregular rainfall, and poor groundwater management [2].The suitability of groundwater for drinking and irrigation depends on its geochemistry, with each system having a distinct chemical composition. Changes in this composition are influenced by factors like rock-water interaction, mineral dissolution, soil-water interaction, duration of contact, temperature, and human activities [7].

Iron is the second most abundant metal and the most prevalent heavy metal in the Earth's crust, constituting over 85% of its mass [6]. Its concentration varies with depth, and it naturally enters groundwater through the weathering of iron-rich minerals and rocks [1]. Iron enters groundwater naturally through the decay of iron (Fe^-) containing rock and minerals, with concentrations varying at different depths [11]. Groundwater property is significantly influenced by agricultural, human source land use; whereas forested areas generally have a lesser impact [8]. Elevated iron levels in water can negatively impact agricultural practices, domestic use, industrial applications, and human health.

*Corresponding Author: ***Vimal Kumar***

DOI: https://doi.org/10.21276/AATCCReview.2025.13.01.448

Various age groups, including newborns, children, and adults, are especially vulnerable to the impact of contaminants like iron [15]. Excessive exposure to iron (Fe^-) can raise the harm of increasing conditions such as Huntington's disease, Parkinson's disease, hyperkeratosis, cardiovascular issues pigmentation changes, Alzheimer's disease, diabetes mellitus, along with nephritic, respiratory, neurological and liver problems [9]. Soil and water chemistry play a significant role in agricultural crop production. Water chemistry is primarily determined by the levels of HCO_3^-, CO_3^{2-}, Cl^-, pH, Ca^{2+}, Mg^{2+}, EC, Na^+, K^+, which influence the SAR and RSC levels in the water. Based on these factors, the irrigation water samples from the study area are classified as C1S1, which is considered suitable for crop production.

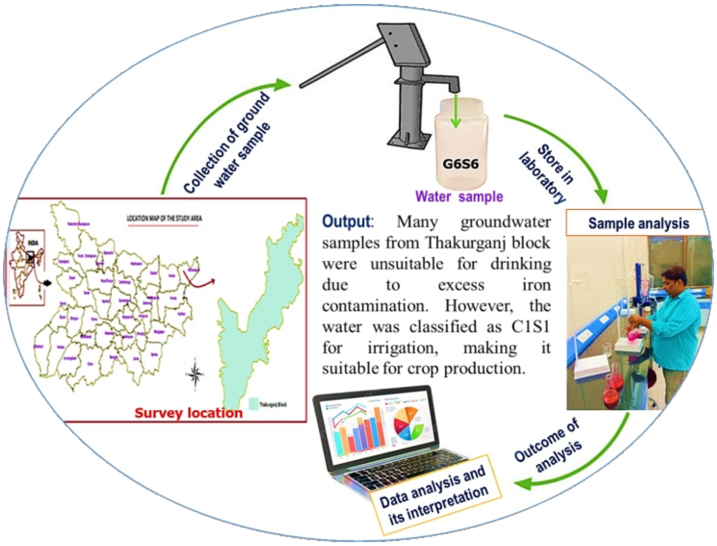
Methodology

GPS-based 55.0 (Fifty-five) in 1000 mL ground-water samples were collected from Thakurganj block of Kishanganj district (Fig.1). The study area is situated on N 26.12159 latitude and E 87.72919 longitude. Thakurganj, block is situated banks of the Mahananda River and soil of this areas is sandy loam and it's very fertile in nature.

Fig.1: Location map of the water sampling area in the Thakurganj block of Kishanganj district, Bihar.

Sample collection and analysis

Water samples were collected from in the month of April to May 2022, in different locations. Collected water samples are store in plastic bottles in 4^0C temperature for the physiochemical properties analysis in a laboratory. After sampling, the bottles were labelled, sealed, and transported to the laboratory in an ice-packed container for further analysis. The water quality indicators analyzed include pH, Ca^{2+}, Mg^{2+}, EC, Na^+, CO_3^-, HCO_3^-, and Cl^-. All analyses were conducted following the standard method outlined in [16].The concentrations of Ca^{2+}, Mg^{2+}, Na^+, CO_3^-, and HCO_3^-, were used to calculate the Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) based on the equation. Irrigation water quality is classified based on EC and SAR values.



Summary of work: Sampling, data analysis, and result interpretation of water samples.

Results and Discussion

Physico-chemical Properties of the Groundwater

The hydrochemical properties of the groundwater are shown in Table 1, detailing the descriptive analysis of the water samples. The parameters analyzed include pH, EC (dS/m), Cl^-, CO_3^{2-}, HCO_3^-, hardness, Ca^{2+}, Mg^{2+}, Na^+, Fe^+, NO_3^-, SAR and RSC. To evaluate the suitability of groundwater for drinking and irrigation, the results were compared with the standard guideline values provided by the World Health Organization [15] and the Bureau of Indian Standards [4]. Table 1 presents the mean values, standard deviations, and range of the obtained results.

Cations in Groundwater

Cations are positively charged ions found in groundwater that contribute to the water's mineral content. The cations analyzed in this study include Ca^{2+}, Mg^{2+}, Na^+, and Fe^+.

The concentration of calcium ranges from 4.70 to 17.50 mgL^{-1}, with a mean value of 10.013 mgL^{-1}(Table 1). Calcium is one of the most common constituents in groundwater, derived mainly from the dissolution of calcium-bearing rocks such as limestone and gypsum. The levels observed in this study fall within the permissible limits for drinking water. Magnesium concentrations range from 7.5 to 24.7 mgL^{-1}, with a mean value of 13.57 mgL^{-1}(Table 1). These concentrations are below the permissible limit of 50 mgL^{-1}[15], [4]. Magnesium, like calcium, is commonly sourced from the weathering of magnesium-bearing minerals like dolomite and magnesium silicates. The higher levels of magnesium contribute to the hardness of the water. Sodium concentrations in the study area range from 1.70 to 9.50 mgL^{-1}, with a mean value of 5.22 mgL^{-1} (Table 1). This is well within the permissible limit of 200 mgL^{-1}[4]. However, high sodium levels can affect soil permeability and structure in agricultural areas, causing soil salinity or alkalinity. Iron concentrations range from 0.080 to 1.840 mgL^{-1}, with a mean value of 0.637 mgL^{-1} (Table 1). Several samples exceeded the permissible limit of 1 mgL^{-1} for drinking water [4], [13]. Elevated iron concentrations are common in groundwater, leading to staining and toxicity in irrigation water.

Anions in Groundwater

Anions are negatively charged ions found in groundwater that contribute to water's chemical composition. The anions analyzed in this study include chloride (Cl^-), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), and nitrate (NO_3^-).

The chloride concentration is an important indicator of salinity. In this study, chloride concentrations range from 1.00 to 25.00 mgL^{-1} (Table.1), which are within the acceptable limits for both drinking and irrigation purposes. The concentration of carbonate ranges from 0.0 to 0.012 mgL^{-1} (Table.1). Carbonate ions are typically introduced into groundwater from the dissolution of minerals like limestone and dolomite during weathering. The low concentrations observed indicate limited carbonate dissolution in the study area. Bicarbonate concentrations range from 0.0 to 0.012 mgL^{-1} (Table.1). Bicarbonate ions are commonly produced through the dissolution of carbonates during weathering processes [1]. Their concentration is generally low, indicating minimal influence from carbonate minerals. Nitrate concentrations range from 1.2 to 8.30 mgL^{-1}, with a mean value of 4.476 mgL^{-1} (Table.1). Nitrate concentrations in the study area were found to be within the permissible limits for drinking water. Nitrate contamination in groundwater is typically linked to agricultural practices, such as the use of nitrogenous fertilizers, and can pose health risks if present in high concentrations.

Sodium Adsorption Ratio (SAR)

SAR ranges from 0.422 to 5.750, with a mean value of 1.363 (Table 1). SAR is a key parameter for assessing the suitability of water for irrigation. Higher SAR values can lead to soil degradation by disrupting soil structure and reducing permeability.

Residual Sodium Carbonate (RSC)

The RSC ranges from -21.050 to -6.397, with a mean value of -11.788 (Table 1). Higher RSC values indicate an increased potential. For sodium absorption by soil particles, which can lead to long-term soil deterioration [3].

Table 1: List of inbreds used in the study

	pH	EC	Hardness	Ca	Mg	Fe	HCO_3	Nitrate	Na	SAR	RSC
Mean	5.879	0.557	165.55	10.013	13.57	0.637	0.001	4.476	5.227	1.363	-11.788
Median	5.840	0.55	168.00	9.400	12.70	0.620	0.000	4.800	5.200	1.070	-10.993
SD	0.499	0.254	27.37	3.020	4.21	0.447	0.003	1.707	1.948	0.886	3.533
Kurtosis	0.042	0.034	1.04	-0.116	0.60	0.846	6.041	-0.698	-0.452	10.549	0.277
skewness	0.118	0.506	-0.32	0.521	0.91	1.022	2.434	-0.098	0.353	2.767	-0.725
Range	2.310	1.050	138.70	12.800	17.20	1.760	0.012	7.100	7.800	5.328	14.653
Minimum	4.850	0.160	89.80	4.700	7.50	0.080	0.000	1.200	1.700	0.422	-21.050
Maximum	7.160	1.210	228.50	17.500	24.70	1.840	0.012	8.300	9.500	5.750	-6.397

Classification of irrigation water

In this area, the water table is very shallow, making it easily available for both irrigation and drinking purposes. Most of the groundwater is used for irrigation, and the salt concentration in the water samples was found to be very low. The analyzed water samples were classified based on the criteria provided [12], [10]. All 55 groundwater samples were classified under the C1S1 class (Table 2), which is considered to be in the safe zone for irrigation.

Table.2: Classification of irrigation water quality parameters suitability

S.No.	Latitude	Longitude	Class	Permeability index (PI)	Remark
1	26.47822	88.17534	C1S1	15.8	Suitable for irrigation
2	26.45035	88.15035	C1S1	5.2	Suitable for irrigation
3	26.43339	88.14011	C1S1	8.0	Suitable for irrigation
4	26.43004	88.13739	C1S1	22.7	Suitable for irrigation
5	26.41187	88.12493	C1S1	23.9	Suitable for irrigation
6	26.39891	88.11326	C1S1	16.4	Suitable for irrigation
7	26.37062	88.08015	C1S1	15.1	Suitable for irrigation
8	26.36601	88.07531	C1S1	22.0	Suitable for irrigation
9	26.35686	88.06793	C1S1	20.5	Suitable for irrigation
10	26.35383	88.06328	C1S1	17.0	Suitable for irrigation
11	26.34483	88.05493	C1S1	12.1	Suitable for irrigation
12	26.3374	88.04677	C1S1	8.4	Suitable for irrigation
13	26.33152	88.04205	C1S1	12.3	Suitable for irrigation
14	26.31844	88.03156	C1S1	13.3	Suitable for irrigation
15	26.30843	88.02567	C1S1	17.8	Suitable for irrigation
16	26.28468	88.00235	C1S1	11.6	Suitable for irrigation
17	26.28744	87.99716	C1S1	11.7	Suitable for irrigation
18	26.2902	87.99724	C1S1	16.0	Suitable for irrigation
19	26.30136	87.99009	C1S1	16.7	Suitable for irrigation
20	26.31699	87.98184	C1S1	10.5	Suitable for irrigation
21	26.32711	87.98094	C1S1	17.4	Suitable for irrigation
22	26.33296	87.98868	C1S1	10.7	Suitable for irrigation
23	26.33591	87.99312	C1S1	20.2	Suitable for irrigation
24	26.33886	87.99867	C1S1	17.7	Suitable for irrigation
25	26.3463	88.0176	C1S1	27.3	Suitable for irrigation
26	26.3493	88.02545	C1S1	22.6	Suitable for irrigation
27	26.35081	88.03214	C1S1	13.2	Suitable for irrigation
28	26.35382	88.04115	C1S1	16.2	Suitable for irrigation
29	26.35685	88.04354	C1S1	23.0	Suitable for irrigation
30	26.36141	88.05048	C1S1	11.6	Suitable for irrigation
31	26.36446	88.05401	C1S1	27.9	Suitable for irrigation
32	26.40214	88.08047	C1S1	13.6	Suitable for irrigation
33	26.40698	88.08315	C1S1	36.9	Suitable for irrigation
34	26.41185	88.0847	C1S1	18.4	Suitable for irrigation
35	26.42831	88.09188	C1S1	10.9	Suitable for irrigation
36	26.44004	88.09875	C1S1	19.2	Suitable for irrigation
37	26.45537	88.10723	C1S1	11.9	Suitable for irrigation
38	26.49782	88.1319	C1S1	39.4	Suitable for irrigation
39	26.49964	88.13696	C1S1	10.3	Suitable for irrigation
40	26.48705	88.1452	C1S1	19.6	Suitable for irrigation
41	26.45038	88.16331	C1S1	17.3	Suitable for irrigation
42	26.43683	88.17206	C1S1	10.5	Suitable for irrigation
43	26.27377	87.95276	C1S1	5.5	Suitable for irrigation
44	26.28193	87.95275	C1S1	32.8	Suitable for irrigation
45	26.42679	88.16835	C1S1	28.3	Suitable for irrigation

46	26.3974	88.14386	C1S1	15.4	Suitable for irrigation
47	26.3584	88.10911	C1S1	35.0	Suitable for irrigation
48	26.31416	88.06149	C1S1	16.0	Suitable for irrigation
49	26.30845	88.05571	C1S1	24.2	Suitable for irrigation
50	26.29717	88.04109	C1S1	33.5	Suitable for irrigation
51	26.29159	88.03334	C1S1	22.5	Suitable for irrigation
52	26.28331	88.0255	C1S1	28.1	Suitable for irrigation
53	26.27784	88.01788	C1S1	26.2	Suitable for irrigation
54	26.2657	87.9986	C1S1	42.6	Suitable for irrigation
55	26.27784	87.96956	C1S1	27.5	Suitable for irrigation

Correlation between different water quality parameters

Pearson's correlation coefficient was computed to evaluate the strength and direction of the relationships between different groundwater quality parameters (Table.3). A higher correlation coefficient indicates a stronger and more meaningful relationship between the variables [5].

Significant positive correlations were observed between the following pairs of parameters: pH and HCO_3^- (r = 0.225**), pH and RSC (r = 0.120**), EC and NO_3^- (r = 0.128**), EC and Na^+ (r = 0.154**),EC and RSC (r = 0.188**), Hardness and Ca^{2+}(r = 0.123**), Hardness and Mg^{2+} (r = 0.131**), Hardness and SAR (r = 0.227**), Ca^{2+} and Mg^{2+} (r = 0.908**), Ca^{2+} and Fe^+ (r = 0.423**), Ca^{2+} and NO_3^- (r = 0.152**), Mg^{2+} and Fe^+ (r = 0.408**), Mg^{2+} and NO_3^- (r = 0.156**), HCO_3^- and SAR (r = 0.155**), NO_3^- and Na^+ (r = 0.191**), Na^+ and SAR (r = 0.551**), Na^+ and RSC (r = 0.232**), SAR and RSC (r = 0.313**). All correlations were significant at the 0.005 level (Table 3).

Table.3: Correlation between different water quality parameters

	pH	EC	Hardness	Ca	Mg	Fe	HCO_3	NO_3	Na	SAR	RSC
pH	1.000										
EC	0.011	1.000									
Hardness	-0.041	-0.067	1.000								
Ca	-0.126	-0.180	0.123**	1.000							
Mg	-0.111	-0.187	0.131**	0.908**	1.000						
Fe	-0.083	-0.260	0.026*	0.423**	0.408**	1.000					
HCO_3	0.225**	-0.136	0.041*	0.083*	0.074*	0.015*	1.000				
NO_3	-0.276	0.128**	-0.056	0.152**	0.156**	0.032*	-0.433	1.000			
Na	-0.175	0.154**	0.089*	-0.263	-0.201	-0.208	-0.190	0.191**	1.000		
SAR	0.096*	-0.001	0.227**	-0.317	-0.297	-0.116	0.155**	-0.588	0.551**	1.000	
RSC	0.120**	0.188**	-0.130	-0.968	-0.984	-0.424	-0.079	-0.159	0.232**	0.313**	1.000

Availability of iron (Fe^+) under different water samples

Heavy metal contamination, such as iron, is a significant issue in the Thakurganj block. The suitability of water quality is determined by the concentration and type of contaminants present. The concentration and availability of iron in relation to different water quality parameters are represented in the graphs (Graph 1a - 1e).

Iron (Fe^+) availability was found to be highest between a pH range of 5.5–6.5, with an R^2 value of 0.0253 (Fig.2.a). The water samples in this range were observed to be acidic in nature. The most suitable conditions for iron availability were found in water samples with electrical conductivity ranging from 0.4–0.8 dS/m, yielding an R^2 value of 0.0843 (Fig. 2.b). Iron availability was maximized when calcium concentrations ranged between 6–10 mgL^{-1}, with an R^2 value of 1.075 (Fig.2.c). Magnesium, an important cation, also affects the availability of iron. The most suitable concentration for iron availability was observed between 7–15 mgL^{-1} of magnesium, with an R^2 value of 0.0986 (Fig. 2.d). Lower sodium concentrations promote higher iron availability. A sodium concentration range of 4–6 $mgL^{-1}$was associated with increased iron concentration in water samples, with an R^2 value of 0.0131 (Fig. 2.e).

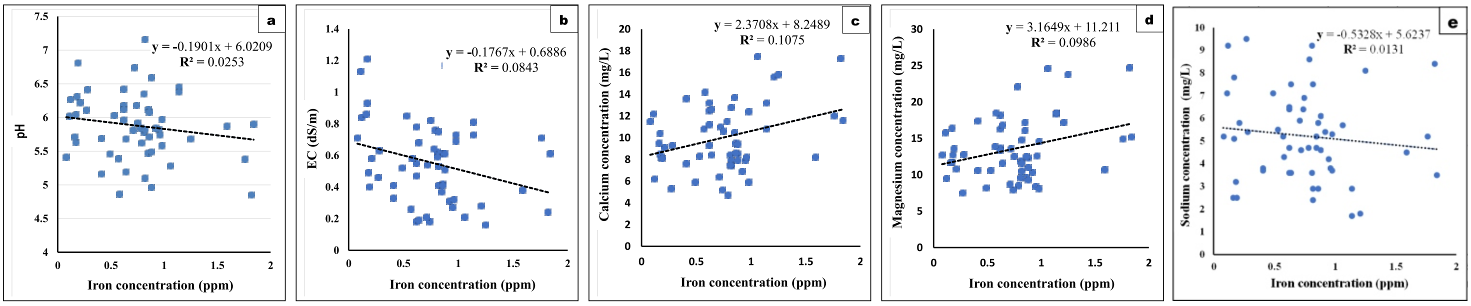


Fig. 2: Availability of iron under different water quality parameters: 2a) pH and iron concentration, 2b) EC and iron concentration, 2c) calcium concentration and iron concentration, 2d) magnesium concentration and iron concentration, and 2e) sodium concentration and iron concentration.

Conclusion

The study was conducted to assess the current status of groundwater and its physicochemical properties for drinking and irrigation purposes in the Thakurganj block, Kishanganj district, Bihar. The analytical results indicate that the groundwater is slightly acidic in nature, with minimal salt accumulation. Regarding its suitability for drinking, many samples were found to be unsuitable due to elevated iron concentrations. However, the water quality for irrigation purposes falls within safe limits. All the analyzed water samples for irrigation purposes were classified under the C1S1 category, which is considered very suitable for crop production.

Reference

1. Bhunia G. S. Keshavarzi A. Shit P. K. Omran E. S. E. and Bagherzadeh A. 2018. Evaluation of groundwater quality and its suitability for drinking and irrigation using GIS and geostatistics techniques in semiarid region of Neyshabur Iran. Applied Water Science 8(6): 1-16.

2. Bichi M. H. and Bello U. F. 2013. Heavy metal pollution in surface and ground waters used for irrigation along river Tatsawarki in the Kano Nigeria. IOSR Journal of Engineering 3(8): 1-9.

3. Bryan G. H. Donald A. H. Robert G. S. Jason W. and Dan M. S. 2007. Managing irrigation water quality for crop production in the Pacific Northwest. A Pacific Northwest Extension Publication 597.

4. Bureau of Indian Standards (BIS). 2012. Specification for drinking water (IS: 10500). Bureau of Indian Standards.

5. Patil, V. T., & Patil, P. R. 2011. *Groundwater Quality of Open Wells and Tube Wells around Amalner Town of Jalgaon District, Maharashtra, India. E-Journal of Chemistry, 8(1), 53–58.* doi:10.1155/2011/676213.

6. Pezzetta, E., Lutman, A., Martinuzzi, I., Viola, C., Bernardis, G., &Fuccaro, V. 2010. Iron concentrations in selected groundwater samples from the lower Friulian Plain, northeast Italy: importance of salinity. *Environmental Earth Sciences, 62(2), 377–391.* doi:10.1007/s12665-010-0533-3.

7. Pincetti-Zúniga G. P. Richards L. A. Tun Y. M. Aung H. P. Swar A. K. Reh U. P. Khaing T. Hlaing M. M. Myint T. A. Nwe M. L. and Polya D. A. 2020. Major and trace (including arsenic) groundwater chemistry in central and southern Myanmar. Applied Geochemistry 115: 104535.

8. Rahman M. M. Hoque S. M. Jesmin S. Rahman M. S. and Kim J. E. 2005. Assessment of groundwater quality for irrigation and agro-based industrial usage in selected aquifers of Bangladesh. Korean Journal of Environmental Agriculture 24(2): 98-105.

9. Sankhla M. S. and Kumar R. 2019. Contaminant of heavy metals in groundwater & its toxic effects on human health & environment. SSRN.

10. Shahid S. A. and Mahmoudi H. 2014. National strategy to improve plant and animal production in the United Arab Emirates. Soil and Water Resources Annexes.

11. Thapa, R., Gupta, S., & Reddy, D. V. 2017. Application of geospatial modelling technique in delineation of fluoride contamination zones within Dwarka Basin, Birbhum, India. Geoscience Frontiers, 8(5), 1105–1114. doi:10.1016/j.gsf.2016.11.006

12. United States Salinity Laboratory (USSL). 1954. Diagnosis and improvement of saline and alkali soils (USDA Handbook No. 60). Washington DC: U.S. Government Printing Office.

13. Verma D. K. Bhunia G. S. Shit P. K. and Tiwari A. K. 2018. Assessment of groundwater quality of the central Gangetic Plain area of India using geospatial and WQI techniques. Journal of the Geological Society of India 92(6): 743–752.

14. World Health Organization (WHO). 2017. Guidelines for drinking-water quality: Training pack (4th ed.). Geneva Switzerland: WHO.

15. Wu J. Yunus M. Islam M. S. and Emch M. 2016. Influence of climate extremes and land use on fecal contamination of shallow tubewells in Bangladesh. Environmental Science & Technology 50(5): 2669–2676.

16. Zhang X. Hu B. X. Wang P. Chen J. Yang L. Xiao K. and Zhang X. 2018. Hydrogeochemical evolution and heavy metal contamination in groundwater of a reclaimed land on Zhoushan Island. Water 10(3): 316.