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An appraisal of ground water quality using statistical analysis in Varanasi district, Uttar Pradesh, India

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Abstract

This present study intended to appraise of the Groundwater quality using statistical analysis in Varanasi district, Uttar Pradesh. During the year 2018, sixteen ground water samples were taken at different locations in the study area, as well as ten parameters such as pH, electrical conductivity (EC), total hardness (TH), calcium (CA), magnesium (MG), sodium (NA), potassium (K), bicarbonate, chloride and fluoride. The very strong positive correlation are reflected in between total hardness and magnesium (0.852), electrical conductivity and sodium (0.821), sodium and fluoride (0.892) and bicarbonate and fluoride (0.715) whereas, the strong negative correlation are observed in between pH and calcium (CA) and potassium and fluoride. The rate of groundwater quality index (WQI) is from 14.59 to 413.01. The higher value of WQI is observed at Arla (S3) block due to higher value of pH, electrical conductivity (EC), fluoride, chloride & sodium.

Keywords: Statistical analysis, Water quality index, groundwater, correction coefficient, Varanasi.

Introduction

Water quality is essential for the promotion of agricultural production, human health and social development. The irregularity and overexploitation of groundwater has affected the quality and quantity of groundwater. Due to irregular and over exploitation of groundwater, quality and quantity of groundwater is affected. Each groundwater system in the area has a distinct chemistry that it gained as a result of the meteor water recharge system's chemical change. Rainwater undergoes chemical changes as a result of interactions between the soil and the water, mineral species dissolution, and human activity[1-7].

Location, Topography and Geology of the study Area: The study area is bounded in north by Ghazipur district, in south by Mirzapur district, in East by Chandauli district, in Northwest by Jaunpur district and in southwest by Sant Ravidas Nagar district (Figure-1). The study area falls in Survey of India top sheet nos. 63K/5 and 15 at 1:50,000 scales, located between latitudes 25º 10'30'' N to 25º 35'15'' N and longitudes 82º 40' 50'' E to 83º 12' 18''E. The area is drained by the Ganga river, which Hindus have long respected, as well as its tributaries, the Gomti, Varuna, Asi, Banganga, Chandra Prabha, and Karmanasa[8].

Geologically, the study area is a part of the Indo-Gangetic plain, which was a consisted Quaternary alluvial deposit from the Pleistocene to present age. However, the unconsolidated sediments from a sequence of clays and sands of various grades are present in the studied region. At various depths, nodular calcareous concretions (Kankars) can intercalate with sands to produce potential aquifers. Clay kankar and meander river deposits are the primary environments for shallow aquifers. Deep aquifers are found in substantial sand layers and have great potentials[9-11].

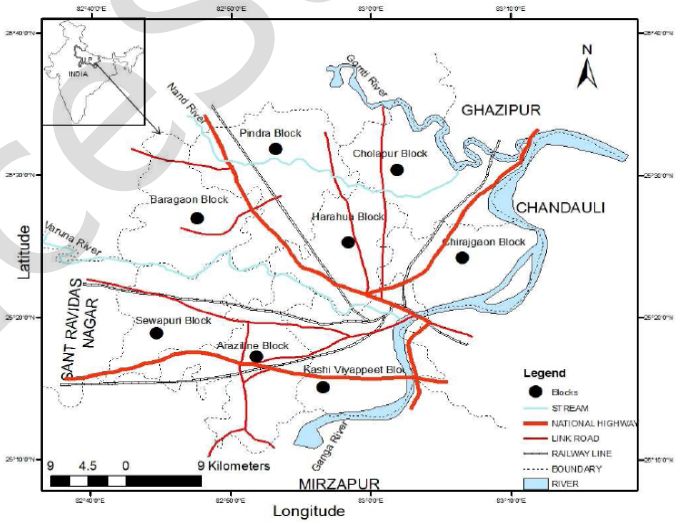

Figure-1: Location of study area[8].

Methodology

Groundwater samples data of year 2018 were collected from the Central Ground Water Board (CGWB), relating to sixteen blocks of Varanasi district, Jakhan (S1), Rajatalaab (S2), Arla (S3), Babatpur Chauraha (S4), Rustampur (S5), Barwaan/ Barwapur (S6), Cholapur (S7), Choubepur (S8), Kakrahwan (S9), Varanasi (S10), Babatpur (S11), Tahipur (S12), Bindhawa

(S13), Sisua/ Soguncha (S14), Phulpur (S15) and Thatra (S16). Ten parameters, including pH, electrical conductivity (EC), total hardness (TH), calcium (CA), magnesium (MG), sodium (NA), potassium (K), bicarbonate, chloride, and fluoride, were examined in the groundwater samples (Table-2). In Table-3, the summary of the groundwater are characterized with Indian Standard/ Bureau of Indian Standards BIS 1991[12].

Table-2: The parameters of Groundwater quality.

Parameters	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
pH	7.98	7.84	8.6	7.92	8.62	8.20	8.08	8.2	8.49	7.65	8.54	8.47	8.12	7.95	8.2	7.76
EC (µs/cm)	485	920	1356	702	818	541.0	508	999	858	928	785	900	855	602	838	600
TH (mg/L)	190	300	60	215	280	175.0	190	315	280	310	120	260	220	225	340	260
CA (mg/L)	36	44	12	32	12	24.0	20	28	12	60	12	16	28	24	44	56
MG (mg/L)	24	46	7.3	33	61	28.0	34	60	61	39	22	54	36	40	56	29
NA (mg/L)	29	87	313	69	74	55.0	40	84	78	63	132	98	102	48	55	23
K (mg/L)	2.3	4.7	1	5.5	2.5	3.40	4	3.2	5.1	4	2.1	1.3	2.1	3.8	3.9	2.7
Bicarbonate (mg/L)	293	500	647	366	329	329.0	317	305	317	305	348	403	500	360	512	329
Chloride (mg/L)	14	43	28	35	35	11.0	14	128	78	92	21	43	14	14	21	28
Fluoride (mg/L)	0.45	0.63	5	0.21	0.78	0.77	0.23	0.78	0.56	0.29	0.5	2.2	0.81	0	0.82	0.63

Table-3: The groundwater parameters with Indian Standard Indian Standard.

Sr. No.	Parameters	Indian Standard/ BIS (Sn)
1.	pH	8.5
2.	EC	300
3.	TH	300
4.	CA	75
5.	MG	30
6.	NA	50
7.	K	12
8.	Bicarbonate	200
9.	Chloride	250
10.	Fluoride	1

The WQI, or water quality index, measures the general suitability of groundwater for all intended uses. It could be expressed as a score that reflects the combined effect of various groundwater quality parameters[12,13]. The estimation of WQI was made using Weight Arithmatic Index method[14].

In the first step, calculation the unit weight $(w)_n$ factors for each parameter by using the equation[15]:

$$w_n = K / \sum S_n \quad (1)$$

Where: $K = \frac{1}{\frac{1}{S_1} + \frac{1}{S_2} + \ldots + \frac{1}{S_n}}$

S_n = Standard desirable value of the n^{th} parameters (permissible value).

In the second step, calculation the sub index (Q_n) value unit by using the equation[15]:

$$Q_n = \left| \frac{(V_n - V_o)}{(S_n - V_o)} \right| X\ 100 \quad (2)$$

where, V_n = Mean concentration of the n^{th} parameters. V_o = Actual values of the parameters in pure water (generally $V_o = 0$, for most parameters except for pH). Therefore, $V_o = 7$ for the pH parameter.

In the third step, combination of first and second steps, WQI is calculated[15]:

$$WQI = \frac{\sum W_N Q_N}{\sum W_N} \quad (3)$$

Calculated WQI were classified into five groups and shown in Table-6.

Table-4: Range and classification of groundwater[15].

Range	Classification of Groundwater
1-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unsuitable for drinking

Results and discussion

The normal statistics of groundwater quality parameters of samples are presented in Table-5. Table-6 is shown as the correction matrix of groundwater quality parameters. The highly positive correction is observed in between NA & Fluoride (0.892), TH & MG (0.852) and Bicarbonate & Fluoride (0.715). The very negative correlation recorded in between pH & CA (-0.868), TH & NA and K & Fluoride (-0.625) whereas, no correlation is reflected in between NA & Chloride (0.011) and EC & MG (0.052). The details of the water quality index (WQI) rate and classification of groundwater is shown in Table-7 which is appraised bases on standard water quality index Table-3.

Table-5: Normal statistics of Groundwater Quality Parameters.

Parameters	Minimum	Mean	Maximum	Variance	Standard Deviation
pH	7.65	8.16	8.62	0.09	0.31
EC	485.00	793.44	1356.00	49172.80	221.75
TH	60.00	233.75	340.00	5651.67	75.18
CA	12.00	28.75	60.00	243.67	15.61
MG	7.30	39.39	61.00	252.03	15.88
NA	23.00	84.38	313.00	4515.58	67.20
K	1.00	3.23	5.50	1.72	1.31
Bicarbonate	293.00	385.00	647.00	10254.80	101.27

Chloride	11.00	38.69	128.00	1099.16	33.15
Fluoride	0.00	0.92	5.00	1.42	1.19

Table-6: Correction matrix of water quality parameters.

	pH	EC	TH	CA	MG	NA	K	Bicarbonate	Chloride	Fluoride
pH	1.000									
EC	0.406	1.000								
TH	-0.352	-0.046	1.000							
CA	-0.868	-0.168	0.508	1.000						
MG	0.121	0.052	0.852	-0.019	1.000					
NA	0.555	0.821	-0.598	-0.447	-0.420	1.000				
K	-0.472	-0.297	0.470	0.311	0.356	-0.498	1.000			
Bicarbonate	0.239	0.663	-0.265	-0.086	-0.258	0.726	-0.303	1.000		
Chloride	-0.051	0.450	0.521	0.157	0.515	0.011	0.238	-0.273	1.000	
Fluoride	0.522	0.738	-0.495	-0.348	-0.359	0.892	-0.625	0.715	-0.044	1.000

Table-7: The WQI rate and classification of groundwater.

Sample	Location	Water Quality Index	Type of water
S1	Jakhan	46.95	Good
S2	Rajatalaab	66.16	Bad
S3	Arla	413.01	Unsuitable for drinking
S4	BabatpurChauraha	31.96	Good
S5	Rustampur	81.42	Very Bad
S6	Barwaan/ Barwapur	74.92	Bad
S7	Cholapur	32.39	Good
S8	Choubepur	79.94	Very Bad
S9	Kakrahwan	65.08	Bad
S10	Varanasi	36.69	Good
S11	Babatpur	57.18	Bad
S12	Tahipur	190.91	Unsuitable for drinking
S13	Bindhawa	79.71	Very Bad

S14	Sisua/ Soguncha	14.59	Excellent
S15	Phulpur	82.56	Very Bad
S16	Thatra	60.62	Bad

Conclusion

From the correlation analysis, maximum parameters are more or less correlated with each other. The very high correlation is observed between sodium (NA) and fluoride, while the very high negative correlation is found in between pH and calcium (CA). In the study area, two locations (S2 & S11) are shown unsuitable for drinking due to maximum limit of fluoride, electrical conductivity (EC) and sodium (NA).

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