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Groundwater Quality Assessment of Nanjangud Industrial Hub using Statistical Tool

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Abstract: ***Hydrogeochemical data pertaining to thirty five groundwater samples in Nanjangud Industrial area were considered in this research work. The water quality parameters were analyzed for physico-chemical characteristics and correlation analysis was used as a statistical tool. Analysis of groundwater revealed that the parameters like EC, TDS, hardness and chlorides in many sampling points exceeded the limits of BIS Standards. EC varied from 0.4 – 12.7mmho/cm and hardness varied from 112 to 2545 mg/L as $CaCO_3$. The correlation matrix clearly indicated that EC was mainly controlled by, TDS, Chlorides and Hardness in a sequence with high positive correlation(> 0.7). Acidity and Sulphates of the ground water samples indicated negative values of Kurtosis (flat peak). The skewness values for the parameters of concern were positive, indicating that data were distributed in the right direction of the tail. It can be concluded that the results of physico-chemical and statistical analysis depicted the deterioration of groundwater in the Nanjangud Industrial area.***

Keywords: Groundwater, Statistical analysis, Correlation, Physico-chemical, Industrial zone

I. INTRODUCTION

Ground water is the major source of water for drinking, agricultural, and industrial desires. Groundwater is believed to be much cleaner and pollution-free when compared to surface water[1]. It is estimated that approximately 1/3rd population uses groundwater for drinking purposes. Today more than half of the world's population depends on groundwater for survival. The quality of groundwater gets altered during its course of movement through the hydrological cycle and various processes such as evaporation, transpiration, uptake by vegetation, oxidation/reduction, cation exchange, dissociation of minerals, precipitation of secondary minerals, mixing of waters with large quantities of industrial wastes and effluents, leaching of fertilizers and manure pollution [2]. Once the groundwater gets
contaminated, its quality cannot be restarted by stopping the pollutants from the source. Therefore, it becomes very important to regularly monitor the quality of groundwater [1].

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Nanjangud is a town lies on the banks of river Kapila (Kabini), in Mysore district which is 23km from the city of Mysore with Latitude and Longitude of 12.10 and 76.66 respectively. Nanjangud has Industrial hub which is spread across 534 acres (2.16 km^2). There are 36 major industries, 12 medium industries and 35 small scale industries.

Major industries are VKC Sandals (India) Private Limited, Nestle India Ltd, Ray Hans Technologies, AT&S India Pvt Ltd., Bannari Amman Sugars Ltd, South India Paper Mills, Reid & Taylor and many more.

II. MATERIALS AND METHODOLOGY

A. Sampling points & collection details

In the present research study, an attempt is being made to analyze the quality of groundwater in the vicinity of industrial area using physico-chemical and statistical analysis to check the influence of industries on ground water contamination.

Grab sampling was adopted to collect groundwater samples and these samples were collected and analyzed as per the Standard Methods (1995). Clean plastic containers of 2L capacity were used to collect the samples. Initially, the containers were rinsed in the sample water two times and then the water sample was collected. The so collected samples were stored at 4ºC in cooler in the laboratory to avoid changes in physico-chemical characteristics. The groundwater samples from 15 open wells and 20 bore wells collected from thirty five sampling points in the industrial vicinity from February to June (Pre monsoon) on monthly basis and labelled as S1 to S35 for easy identification. The sampling stations S1 to S7 were located near Jubilant Generic Limited industry, stations S8 to S16 were located near Kallahalli and S17 to S32 in Basavanapura and S33 to S35 near to South India Paper Mill. The details of sampling points are furnished in Table 1 and Google Image 1.

Table 1: Description of sampling stations

Sl .No.	Sampling station	Type of well	Description
1	S1	Bore well	In house 100 m away from Jubiliant industry with poor maintenance, water used for washing purpose
2	S2	Open well	75 m away from jubilant industry (Not used)
3	S3	Open well	Inside farm 150 m away from jubilant industry used for coconut and other plantations
4	S4	Bore well	Bore Well 180 m away from jubilant industry
5	S5	Bore well	New Bore Well in agricultural land 300 m away from jubilant used for plantation
6	S6	Bore well	350 m away from jubilant Industry used for irrigation
7	S7	Open well	Near temple 50 m away from jubilant industry used for washing and irrigation
8	S8	Open well	In agricultural field, used for irrigation. 2km away from jubilant industry
9	S9	Bore well	Inside house, used for all purpose except drinking
10	S10	Bore well	Near school, supplied for drinking purpose
11	S11	Bore well	New bore well, house under construction
12	S12	Bore well	New bore well, house under construction, 50m away from S11
13	S13	Bore well	Near Anganvadi school and very near to drain
14	S14	Open well	Inside the house, used for all purpose, well maintained
15	S15	Open well	Inside the house, not used for any purpose, not maintained properly
16	S16	Bore well	In front of house, maintained properly, near to drain
17	S17	Bore well	Inside the school compound, Basavanapura, not in good condition
18	S18	Open well	In the house compound, used for all purpose except drinking
19	S19	Open well	In the house, near to open drain, not maintained properly Basavanapura
20	S20	Bore well	Bore Well in school, Basavanapura
21	S21	Open well	In school, Basavanapura
22	S22	Open well	Inside house used for all purpose except drinking
23	S23	Bore well	Outside the house, Basavanapura
24	S24	Bore well	Outside the house, Basavanapura
25	S25	Bore well	New house, Basavanapura
26	S26	Open well	Open well maintained properly
27	S27	Bore well	In temple, 200m away from Danford industry Basavanapura
28	S28	Bore well	Inside the storage room of VKC sandals , Basavanapura
29	S29	Open well	Inside house, used for agriculture, Basavanapura
30	S30	Open well	Not used and not maintained properly, Basavanapura
31	S31	Bore well	Not maintained properly, near to drain, Basavanapura
32	S32	Open well	Used for agriculture, Basavanapura
33	S33	Bore well	In temple, maintained well near to South India Paper mill
34	S34	Bore well	Inside temple, maintained properly near to South India paper mill
35	S35	Open well	Inside house, used for all purpose except drinking

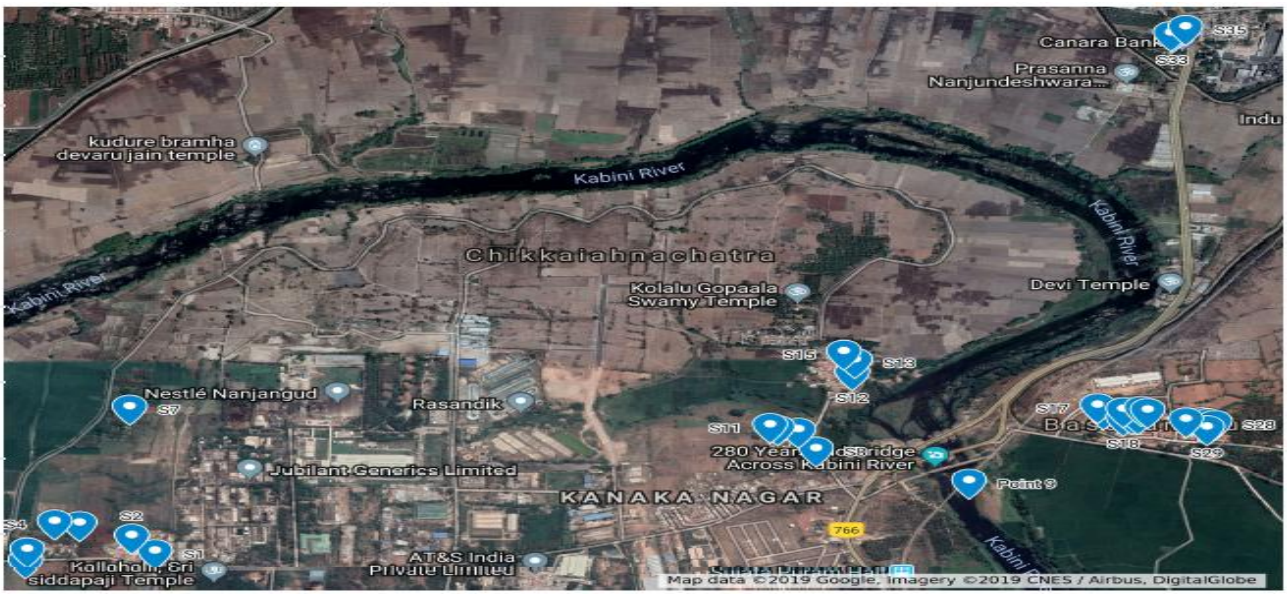

Image 1: Sampling point

The routine water quality parameters analyzed were pH, Electrical conductivity, Acidity, Alkalinity, Calcium hardness, Total hardness, Sulphates, Nitrates, Iron, Chlorides, Turbidity, BOD_5, Fluorides and Total Dissolved solids and correlation matrix of statistical analysis were adopted.

III. RESULTS AND DISCUSSION

The results obtained for physico-chemical characteristics is presented in Table 2. The results were evaluated in accordance with the Standards prescribed under Indian Standard drinking water Specifications IS:10500:2012 of Bureau of Indian Standards.

The presence of carbonates, bicarbonates, and hydroxides was the main cause of alkalinity in natural waters. Bicarbonates represent the major form in considerable amount from the action of carbonates upon the basic materials in the soil (3). Alkalinity in the study area varied from 92.1 (S30) to 1154 (S5) mg/L as $CaCO_3$. 49% of samples exceed the limit 200 mg/L as $CaCO_3$. pH varied between 7.0 to 7.8 and all the samples lie within the limit. Electrical conductivity is the capacity of water to conduct current and is caused by the presence of salts, acids and bases, called electrolytes, capable of producing cations and anions. The major ions present in water causing EC are chlorides, sulphates, carbonates and bicarbonates, nitrates, calcium, magnesium, sodium and potassium [4].

The high variation in EC is largely ascribed to geochemical processes like evaporation, silicate weathering, ion exchange, reverse exchange, rock water interaction, sulphate reduction and oxidation [5]. Electrical conductivity in the study area varied from 0.4 – 12.7mS/cm. All the samples exceed the limit of 0.5mS/cm.

Turbidity in water may be due to wide variety of suspended materials, which range in size from colloidal to coarse dispersions, depending upon the degree of turbulence. Turbidity in the study area range from 0.5 – 34.8 NTU with a mean of 4.9 NTU and 26.32% of groundwater samples were found exceeding the acceptable limits of BIS. Four samples exceed the permissible limit of 5 NTU. Turbidity is caused by particles suspended or dissolved in water that scatter light making the water appear cloudy or murky. Particulate matter can include sediment - especially clay and silt, fine organic and inorganic matter, soluble colored organic compounds, algae, and other microscopic organisms.

The principal hardness causing cations are calcium, magnesium, strontium, ferrous and manganese ions. The cations plus the most important anions that contributes are bicarbonates, sulphates, chlorides, nitrates and silicates [5]. Total hardness varied from 112mg/L to 2545 mg/L as $CaCO_3$ with mean value of 566 mg/L and 34% of groundwater in the study area exceeded the permissible limit (Table 2).

Chloride, in the form of Cl^- ion, is one of the major inorganic anions in water and wastewater. The salty taste produced by chloride concentrations is variable and dependent on the chemical composition of water. Some water containing 250 mg/L may have a detectable salty taste if the cation is sodium. On the other hand, the typical salty taste may be absent in water containing as much as 1000 mg/L when the predominant cations are calcium and magnesium [6]. The chloride content in groundwater varies from 45.6 to 1872.4mg/L mg/L. Thirteen samples in the study area exceeded the desirable limit of 250 mg/L recommended by BIS.

The high concentration of iron in groundwater might be due to rusting of casing pipes, non-usage of bore wells for a long time, percolation of iron contaminants through space between bore hole and the casing pipe, disposal of scrap iron in open areas, contamination due to industrial activities etc., [7]. Only sample S1 exceeded the limit of 0.3mg/L and all other samples were within the limit. High fluoride concentrations may therefore be expected in ground waters from calcium-poor aquifers and in areas where fluoride-bearing minerals are common. Sixteen samples were in the range between 1.0 to 1.5 mg/L of BIS limit. 18 samples were found to be less than 1.0 mg/L and remaining one sample exceed 1.5 mg/L. TDS in water originates from natural sources, urban and agricultural run-off, domestic and industrial wastewater. It varied from 38.1to 612.2mg/L. Average value in Tables 2 showed except sample S8, TDS values of all the samples lies in the acceptable limit of 500mg/L of BIS. Sulphate in the study area varied between 13.3 to 58.6 mg/L with a mean value of 31.31 mg/L and it was found that none of the water samples exceeded the limit of 200 mg/L. The high nitrate concentration of nitrate could have resulted from the seepage of the liquids due to the occurrence of sewage and septic tanks, industrial effluents, and agricultural chemicals nearby [8]. The high nitrate concentration of nitrate could have resulted from the seepage of the liquids due to the occurrence of sewage and septic tanks, industrial effluents, and agricultural chemicals nearby. Nitrate concentration varied up to 3.1 mg/L which indicates that groundwater has not been affected by nitrate.

Table 2: Results obtained for physico-chemical characteristics

Sampling points	pH	Electrical conductivity (m-mho)	Acidity (mg/L as $CaCO_3$)	Alkalinity (mg/L as $CaCO_3$)	Calcium hardness (mg/L as $CaCO_3$)	Total hardness (mg/L as $CaCO_3$)	Sulphates (mg/L)	Nitrates (mg/L)	Iron (mg/L)	Chlorides (mg/L)	Turbidity (NTU)	BOD_5 (mg/L)	Fluorides (mg/L)	Total Dissolved solids (mg/L)
S1	7.5	3.5	60.1	536.6	856.4	1047.3	43.0	0.7	0.6	458.9	34.8	7.1	0.4	183.8
S2	7.2	2.9	68.4	403.3	504.1	825.1	21.8	0.2	0.0	458.7	2.7	3.8	0.4	158.3
S3	7.3	3.6	46.4	334.0	547.6	786.3	23.7	0.1	0.0	579.1	3.1	3.9	0.4	204.0
S4	7.2	4.3	51.6	912.7	819.6	969.9	43.1	0.3	0.0	621.9	14.6	3.1	0.4	221.4
S5	7.7	3.4	78.3	1154.3	327.7	444.1	23.2	0.8	0.1	763.1	13.3	3.8	0.8	143.9
S6	7.4	4.4	59.4	516.6	312.1	568.1	22.1	0.1	0.0	326.1	1.4	4.0	0.5	233.1
S7	7.3	2.3	49.0	263.7	479.7	644.0	35.9	0.3	0.0	483.1	3.4	2.9	1.1	114.1
S8	7.2	10.2	60.1	257.3	875.6	2545.0	42.3	0.5	0.0	1872.4	1.9	4.1	1.5	612.2
S9	7.0	12.7	64.1	371.3	710.9	1742.3	42.5	1.0	0.0	1113.4	4.3	3.5	1.0	420.4
S10	7.2	4.8	40.4	213.3	299.7	684.9	39.1	1.4	0.0	625.4	3.0	5.1	1.9	358.6
S11	7.1	5.2	42.6	193.9	355.1	554.9	36.9	1.2	0.0	631.6	3.6	3.3	0.5	373.0
S12	7.6	4.7	24.0	155.7	393.4	762.7	21.2	1.2	0.1	112.6	2.7	3.2	1.2	243.4
S13	7.8	1.2	27.0	176.6	196.3	309.6	22.1	0.1	0.0	62.6	1.3	2.9	0.4	56.4
S14	7.4	1.6	54.6	305.9	293.1	436.6	22.7	0.0	0.0	175.6	0.5	3.2	0.9	55.6
S15	7.6	0.4	37.7	222.1	272.0	536.3	14.7	0.0	0.0	45.6	0.7	2.8	1.3	76.4
S16	7.4	0.7	31.3	194.0	130.9	222.0	24.1	0.9	0.0	118.3	0.6	1.6	1.3	42.1
S17	7.2	1.4	65.9	196.0	253.0	282.0	30.5	0.9	0.0	175.9	1.3	6.2	1.2	137.3
S18	7.2	2.3	56.4	192.4	247.4	345.0	27.8	0.1	0.0	106.3	1.9	6.5	1.3	369.2
S19	7.3	1.8	35.7	157.1	177.1	277.3	40.0	1.1	0.0	136.1	1.7	4.2	0.9	127.5
S20	7.4	2.0	29.4	115.6	196.0	336.1	16.7	0.4	0.0	126.0	2.0	3.5	0.8	148.7
S21	7.3	1.9	35.0	117.9	244.9	290.3	23.5	0.8	0.1	116.6	1.8	3.2	1.2	146.7
S22	7.2	1.7	27.0	141.0	253.0	365.4	46.8	0.2	0.0	82.1	4.1	6.2	1.4	213.6
S23	7.2	1.8	43.7	295.4	132.4	156.1	13.3	0.0	0.0	208.0	1.8	2.6	1.0	142.0
S24	7.4	1.9	49.7	201.7	134.0	267.0	14.7	0.6	0.2	220.3	2.0	3.1	1.0	201.8
S25	7.3	3.8	20.4	219.3	256.9	571.6	47.7	1.1	0.2	131.1	3.4	4.6	0.9	229.3
S26	7.4	2.6	47.6	216.1	247.9	378.6	19.7	0.1	0.1	106.6	3.4	4.9	0.8	102.8
S27	7.1	2.6	49.1	143.6	187.1	378.0	24.8	0.1	0.1	186.4	33.7	7.7	0.8	306.6
S28	7.5	0.7	41.7	129.9	57.7	172.4	22.7	1.6	0.0	173.9	3.6	4.3	0.6	47.6
S29	7.4	3.3	24.0	174.4	305.9	543.7	45.6	0.8	0.1	119.4	0.6	1.4	1.1	276.1
S30	7.6	3.6	27.7	92.1	417.3	693.4	56.7	0.6	0.1	183.1	4.7	4.5	1.0	310.5
S31	7.1	4.6	44.3	236.0	402.7	857.1	58.6	0.3	0.1	171.6	2.9	4.9	1.1	320.4
S32	7.2	3.7	29.0	166.0	357.6	615.4	31.9	1.5	0.1	145.3	3.0	4.7	1.0	238.4
S33	7.5	0.7	34.6	98.6	59.3	112.0	25.9	1.2	0.0	186.0	2.5	4.5	0.9	91.5
S34	7.5	0.9	42.0	161.0	155.4	221.9	35.3	3.1	0.0	157.4	3.1	3.9	0.9	38.1
S35	7.4	1.1	30.7	152.9	99.3	214.4	35.2	2.1	0.0	130.6	2.0	4.1	0.8	71.9

Table 3: Correlation matrix for ground water quality parameters

	pH	Electrical conductivity	Acidity	Alkalinity	Calcium hardness	Total hardness	Sulphates	Nitrates	Iron	Chloride	Turbidity	BOD_5	Fluorides	Total dissolved solids
pH	1													
Electrical conductivity	-0.233	1												
Acidity	-0.153	0.322	1											
Alkalinity	-0.233	0.241	0.612	1										
Calcium hardness	-0.128	0.914	0.322	0.536	1									
Total hardness	-0.085	0.735	0.432	0.636	0.853	1								
Sulphates	-0.068	0.418	-0.127	0.436	0.416	0.418	1							
Nitrates	0.152	-0.061	-0.234	-0.204	-0.147	-0.235	0.219	1						
Iron	0.141	0.019	0.042	-0.204	0.010	0.275	0.218	0.023	1					
Chloride	-0.177	0.813	0.517	0.397	0.849	0.701	0.229	-0.038	-0.127	1				
Turbidity	-0.009	0.081	0.312	0.297	0.073	0.345	0.119	-0.094	0.648	0.077	1			
BOD_5	-0.088	0.024	0.269	-0.114	-0.020	0.071	0.119	-0.028	0.339	-0.052	0.563	1		
Fluorides	-0.139	0.141	-0.178	-0.310	0.156	-0.109	0.179	0.082	-0.190	0.118	-0.316	0.050	1	
Total Dissolved solids	-0.278	0.937	0.144	0.065	0.814	0.629	0.539	-0.051	0.026	0.731	-0.014	0.061	0.3	1

Table 4 : Statistical evaluation adopted

	Mean	Median	Mode	Standard Deviation	Kurtosis	Skewness	Range	Min	Max	Sample variance
Ph	7.35	7.3	7.2	0.18	-0.12	0.45	7.35	7	7.8	0.03
Electrical conductivity (m-mho/cm)	3.05	2.6	0.7	2.31	5.11	2.01	3.05	0.4	12.7	5.35
Acidity (mg/L as $CaCO_3$)	43.68	42.6	60.1	14.46	-0.52	0.41	43.68	20.4	78.3	209.2
Alkalinity (mg/L as $CaCO_3$)	269.09	196	N/A	219.72	8.76	2.83	269.09	92.1	1154.3	48275.59
Calcium hardness (mg/L as $CaCO_3$)	330.26	272	253	213.54	1.24	1.3	330.26	57.7	875.6	45599.38
Total hardness (mg/L as $CaCO_3$)	566.59	444.1	N/A	425.16	6.28	2.26	566.59	112	2545	180762.1
Sulphates (mg/L)	31.31	27.8	22.1	12	-0.57	0.51	31.31	13.3	58.6	144.12
Nitrates (mg/L)	0.73	0.6	0.1	0.68	3.11	1.46	0.73	0	3.1	0.46
Iron (mg/L)	0.05	0	0	0.11	16.72	3.68	0.05	0	0.6	0.01
Chlorides (mg/L)	323.17	175.6	N/A	362.42	9.44	2.78	323.17	45.6	1872.4	131349.2
Turbidity (NTU)	4.9	2.7	3.4	7.89	10.33	3.26	4.9	0.5	34.8	62.27
BOD_5 (mg/L)	4.09	3.9	3.2	1.4	0.73	0.69	4.09	1.4	7.7	1.95
Fluorides (mg/L)	0.93	0.9	0.4	0.35	0.36	0.31	0.93	0.4	1.9	0.12
Total Dissolved solids (mg/L)	200.48	183.8	N/A	127.34	1.73	1.1	200.48	38.1	612.2	16215.42

A. Statistical analysis

To identify the distribution pattern of the ground water quality parameters, normal distribution analysis was used as a statistical tool. Pearson correlation analysis was carried out to identify the degree of association between the parameters through correlation coefficient value[9]. It provides instinctive similarity relationship between any one sample and entire data set. Pearson's correlation coefficient is usually signified by r (rho), and can take on the values from +1.0 to -1.0. Where -1.0 is a perfect negative (inverse) correlation, 0.0 is no correlation and 1.0 is a perfect positive correlation [10]. Correlation coefficient of the parameters analyzed are calculated and indicated in Table 3.

The analytical data showed close significant positive association of EC with Calcium hardness (r=0.91), Total hardness (r=0.735) and TDS (r=0.937). This clearly indicates that EC increases with increase of these three parameters in groundwater samples. TDS showed positive correlation with Chloride (0.731), Total hardness (r=0.629) and Sulphate (r=0.53). The correlation analysis results indicates the effects of both natural and anthropogenic activity on hydrochemistry.

Table 4 indicates the values of normal distribution analysis obtained for water quality parameters. Referring to Table 4 it can be observed that there is significant variations between mean and median for alkalinity, Calcium hardness, Total hardness, Chloride and Total dissolved solids indicating that these parameters were not found to be completely distributed in a normal and symmetric manner. However, a small difference in mean and median were observed for parameters such as pH, Electrical Conductivity, Acidity, Sulphate, Nitrate, Iron, Turbidity, BOD_5 and Fluoride. This clearly indicated that these parameters were seemed to be normally distributed. Further, pH, acidity and Sulphates had negative values of Kurtosis, indicating flat peak compared to normal distribution pattern.

IV. CONCLUSIONS

In the present research study, physico-chemical characteristics and statistical analysis using correlation matrix were used to investigate the hydro-geochemical characteristics. Of thirty five ground water samples analyzed, the results revealed that the in Nanjangud Industrial area, the parameters such as Electrical conductivity, Hardness and Chlorides in few sampling station exceeded the limits of BIS. This clearly indicated that water at these sampling points was not fit for human consumption without treatment. The Ca^{++} and Mg^{++} ion hardness revealed that groundwater in the study area ranges from hard to very hard. The correlation matrix indicated that EC is mainly controlled by TDS (0.937), Chlorides (0.813) and Hardness (0.735) and there is strong positive correlation between these parameters. The groundwater sources near the industries need immediate attention and monitoring to minimize further pollution. The effluent and industrial waste has to be disposed off only after proper treatment to avoid ground water contamination

REFERENCES

1. Samson S and Elangovan K, "Multivariate Statistical Analysis to assess Groundwater Quality in Namakkal District, Tamilnadu", India, Indian Journal of Geo Marine Sciences, Vol. 46 (04), pp. 830-836, 2017.
2. Meshari Al-Harbi, Fawzia M. Al-Ruwaih, and Abdalrahman Alsulaili,,"Statistical and Analytical Evaluation of Groundwater Quality in Al-Rawdhatain Field", Environmental Progress & Sustainable Energy, Vol.33, No.3, pp.895-904, 2014.
3. Anitha Mary I, Ramkumar T, and Venkatramanan S, "Application of Statistical Analysis for the Hydrogeochemistry of Saline Groundwater in Kodiakarai, Tamilnadu, India", Journal of Coastal Research, Vol.28, pp.89–98, 2012.
4. Khwaja M. Anwar, Aggarwal Vanita, "Analysis of Groundwater Quality using Statistical Techniques: A Case Study of Aligarh City (India), International Journal of Technical Research and Applications, Vol. 2, pp. 100-106, 2014.
5. Desalegn Amenu, "Bacteriological and Physicochemical Quality of Well Water Sources",
6. Research Journal of Chemical and Environmental Sciences, Vol. 2 [5], pp.13-27, 2014.
7. Prakash K L and Somashekar R K, "Groundwater quality - Assessment on Anekal Taluk, Bangalore Urban district, India", Journal of Environmental Biology, Vol.27(4), pp.633-637, 2006.
8. Shamsuddin M K N, Suratman S and Ramli M F Hydrochemical Assessment of Surfacewater and Groundwater Quality at Bank Infiltration Site, Soft Soil Engineering International Conference, 2015.
9. Zeba Khanam and Vir Singh, "Groundwater Quality Assessment near Polluted Canal Area in Kichha Town, Uttarakhand, India, International Journal of Recent Scientific Research, Vol. 5, pp.362-368, 2014
10. Gupta V.S.S.R, Srinivasa Rao R, Divya K, "Evaluation of Groundwater Quality Using Multivariate Statistical Techniques snd GIS - A Case Study", International Journal of Civil Engineering and Technology, Vol. 8, pp. 1165-1176, 2017.
11. Sajil Kumar P. J, "Hydrogeochemical and multivariate statistical appraisal of pollution sources in the groundwater of the lower Bhavani River basin in Tamil Nadu", GEOLOGY, ECOLOGY, AND LANDSCAPES, pp.1-12, 2019.

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