Assessment of Water Quality in the Bore Wells of a Centenary School in Southern Kerala, India

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Abstract: ***The present study aims to evaluate the quality of drinking water from borewells in the Government Higher Secondary School situated at Kazhakuttom in the Trivandrum district of Southern Kerala. Bore well water samples were collected from 12 sampling sites in the school premises during the pre-monsoon, monsoon, and post-monsoon seasons of the year 2018. The physico-chemical, bacteriological and statistical analysis were carried out for evaluating the quality of the drinking water. The results revealed that the concentrations of the majority of the parameters are within the permissible limits of drinking water quality standards except that of iron and lead. The metal index values are less than 1 which means below the threshold limit. Also, there was no evidence of microbial contamination in all the borewells sampled as the total coliform and fecal coliform count was zero. This study recommends that the old rusted iron pipes used for water supply in the school and those with leakage should be replaced with new ones, and the quality of drinking water, with special reference to lead should be checked periodically.***

Keywords: Bore well, Iron, Lead, School, Water Quality Index

1. Introduction

Water is one of the essential commodities that man has exploited than any other resource for his life. Most of our demand for water is fulfilled by rain water which gets deposited in surface and ground water resources [1]. The Joint Monitoring Programme (JMP) for water supply and sanitation, implemented by the World Health Organization (WHO) and UNICEF, reports that 783 million people in the world (11% of the total population) have no access to safe water, 84% of whom live in rural areas. In India, more than 90% of rural population depends on well water for domestic purpose [2]. Bore wells are a successful source of drinking water in many parts of India. They yield bacteriologically safe water and are also cheap in comparison to other sources of supply. In Kerala, about 80% of the Kerala population depends on groundwater for various activities. Among the Kerala districts, the dug well density of Thiruvananthapuram district is 235 wells/sq. km. The depth to water level varies from 0.2 to 5 m below ground level on the Trivandrum coast [3, 4]. The monitoring and evaluation of groundwater quality and chemistry are vital for sustainable management and groundwater source protection. Water is necessary for all metabolic processes as well as maintains thermal stability in the body. Millions of people were exposed to unsafe levels of chemical contaminants through their drinking water. It may be linked to a lack of proper management of urban and industrial wastewater or agricultural run-off water-potentially giving rise to long term exposure to pollutants, which can have a range of profound health implications, or it may be linked to naturally-occurring arsenic and fluoride, which cause cancer and tooth/ skeletal damage, respectively. The quality of drinking water is a powerful environmental determinant of health. Drinking water quality management has been a critical pillar of primary prevention for over one and a half centuries, and it continues to be the foundation for the prevention and control of waterborne diseases [5]. The present study aims to evaluate the drinking water quality of borewells in a 100-years old public high school with more than 1000 students, fifteen teachers and five non-teaching staff.

2. Materials and Methods

Study area: The groundwater sources in the Government Higher Secondary School premises at Kazhakuttom in Thiruvananthapuram district, Kerala, South India was selected for the present study. Location map showing sampling sites in the Govt. Higher Secondary School, Kazhakuttom, Thiruvananthapuram are shown in Figure 1. Bore well water is the primary source of drinking water for the children and staff in this school. It was reported by the school authorities that there are four bore wells on the school premises that are more than 25 years old.15 water taps and two water purifiers are the primary outlets for collecting drinking water for the school students and staff. Pre KG to 10th level classes are there in the high school section, and around 1000 students are studying in this school.

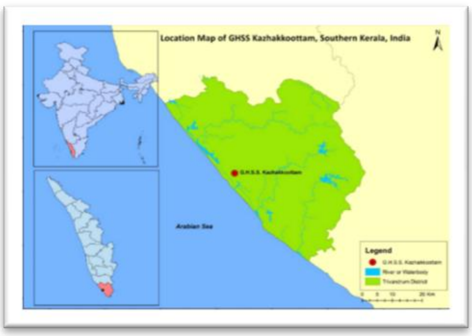

Figure 1: Location map of the Study area

Sample collection: Twelve water samples from bore wells of the school were taken randomly from the outlets of pipes that is, eight from the taps and four from the two purifiers. The sample collection was carried out trimonthly, i.e., April (Pre-monsoon), July (monsoon), and October (Post-monsoon) of the year 2018. Water samples were collected separately in clean polyethylene bottles prewashed with dilute hydrochloric acid and rinsed with the sample before filling it to the required capacity from the selected sampling sites for the analysis of physico-chemical characteristics [6]. For the determination of dissolved oxygen, the water samples were collected in BOD bottles. For the bacteriological analysis, the water samples were collected from the sites in sterilized, labeled glass bottles maintaining aseptic condition and immediately transported in a cooler box containing ice packs to the laboratory with proper care and kept in a refrigerator at 4˚C. The bacteriological analysis was carried out within 48 hours. Immediately after sampling, the samples were carried to the laboratory, and the temperature, pH, electrical conductivity, free CO_2, alkalinity, dissolved oxygen, and sulphate content of water samples were measured immediately.

Methodology: The physical and chemical parameters of well water samples analyzed include temperature, electrical conductivity, total dissolved solids, pH, total alkalinity, acidity, free carbon dioxide, dissolved oxygen, nitrate, phosphate, sulphate, chloride, hardness, calcium, magnesium, sodium, potassium, and iron. The major water quality attributes and heavy metals were estimated following the standard procedures in APHA [7] and Trivedi and Goel [8]. The heavy metals in acid digested water samples were analysed using an Atomic Absorption Spectrophotometer (GBC 932 AA Model, Dandenong, Australia).

Metal Index (MI): is a number which shows the quality of water with respect to the heavy metal concentration in it. The higher the concentration of metal compared to its maximum allowable concentration (MAC) value, the worse the quality of water. If the concentration of a certain element is higher than that of the MAC value (MI >1), the water is considered as contaminated [9]. Metal Index (MI) for a drinking water source can be calculated by the following equation;

$$MI= \sum_{i=1}^{n} \frac{CI}{(MAC)\ I}$$

Where, C = Concentration of each element in a sample

MAC = Maximum Allowable Concentration of that element

Statistical Analysis: The Pearson Correlation coefficient analysis is used to study the nature and strength of the relationship between two variables using the IBM SPSS Statistics. A two-tailed p-value of less than 0.05 was accepted to be statistically significant. The Average, Standard Error, Standard Deviation, Standard Variance, Minimum, Maximum and Confidence Level (95%) were calculated by using the Microsoft Excel (2019).

3. Results & Discussion

The results of the physico-chemical characteristics of borewell water samples collected in April (summer), July (monsoon), and October (Post monsoon) are tabulated in tables **1 to 3**. The results are demonstrated by the minimum and maximum values, average values and statistical variations ie., Standard Deviation (SD), Standard Variance (SV), Standard Error (SE), 95% Confidence limit (CL) of the parameters are presents in tables 1, 2 & 3 and description of correlation coefficient (r) of the water samples is presented in table **4, 5** & **6**.

The pH of the bore well water samples collected from the school area varied from 6.49 to 9.1 during summer, 4.07 to 7.08 in monsoon, and 4.32 to 5.46 in post monsoon. In post monsoon, all the samples showed acidic nature (4.32-5.46), and the pH of samples are below the permissible limit of WHO standards, i.e., 6.5-8.5. The slightly acidic nature of water can be attributed to carbon dioxide incorporated into the groundwater by bacterial oxidation of organic matter. The concentration of average value with 95% CL was found to be 7.80 ± 0.59 in pre monsoon, 5.81±0.72 in monsoon and 4.77± 0.22 in post monsoon seasons respectively. pH showed positive correlation with iron (r= 0.389) in pre monsoon and DO (r= 0.623) in monsoon. All other parameters showed negative correlation with pH.

The electrical conductivity (E. C.) of the well water samples collected in the summer season varied from 68.34 µS/cm and 353.7 µS/cm; in monsoon, it ranged from 66.84 µS/cm to 323.1 µS/cm, and during post monsoon season, it ranged from 241.3 µS/cm to 689.3 µS/cm. The concentration of average value with 95% CL was found to be 187.25 ± 56.58 in pre monsoon, 176.48 ±57.64 in monsoon and 398 ±136.4 in post monsoon seasons respectively. The permissible limit of electrical conductivity is 300µS/cm, and the values obtained during summer are below the permissible limit, except in one station. The conductivity of water samples collected during monsoon and post monsoon showed high values compared to the standard permissible limit of drinking water standards [10].

Total dissolved solids (TDS) denote mainly the various kinds of minerals present in water. The concentration of dissolved solids is an essential parameter in drinking water. In summer, TDS in the water samples collected from the school ranged from 44.54 ppm to 161.4 ppm; in monsoon, it ranged from 32.3 ppm to 149 ppm post monsoon season, it ranged from 130 ppm to 370.1 ppm. The concentration of average value with 95% CL was found to be 88.83±25.4 in pre monsoon, 82.27±27.11 in monsoon and 210.25±72.13 in post monsoon seasons respectively. The results obtained for TDS content in the studied well waters are below the permissible limit [10] ie, 500mg/L. TDS showed negative correlation with DO (r=0.737) in pre monsoon and phosphate (r=0.691) in monsoon. All other physico-chemical parameters showed positive correlation with TDS.

Dissolved oxygen (DO) is one of the most critical water quality parameters and reflects the physical and biological processes prevailing in the waters. Oxygen saturating waters have a pleasant taste, while the waters lacking oxygen have an insipid taste. In the present study, during the pre-monsoon season, DO content in well water varied from 2.84mg/L to 8.53 mg/L, and in monsoon DO content ranges from 4.23 to 6.3 mg/L, and in post monsoon, it ranged from 4mg/L to 6.8 mg/L. The concentration of average value with 95% CL was found to be 5.61±1.13 in pre monsoon, 5.65±0.75 in monsoon and 5.56±0.61in post monsoon seasons respectively.

The chloride content in the water samples varied from 39.76 mg/L to 204.48 mg/L in summer, 21.3 mg/L to 88.04 mg/L in monsoon and 21.3 mg/L to 68.16 mg/L in post-monsoon season. The permissible limit of chloride in drinking water is 250 mg/L [10], and all the samples analyzed showed values less than the permissible limit of water quality standards. The concentration of average value with 95% CL was found to be 88.98±38.45 in pre monsoon 51.21±19.29 in monsoon and 37.01±14.1 in post monsoon respectively. Chloride showed positive correlation with calcium (r=0.836), magnesium (r= 0.784), sodium (r=0.749), potassium (r=0.777), sulphate (r=0.879), nitrate (r=0.725) and phosphate (r=0.547) in pre monsoon, calcium (r=0.826), sodium (r=0.704), potassium (r=0.996), sulphate (r=0.982) and nitrate (r= 0.766) in monsoon and calcium (r=0.949), sodium (r=0.997), potassium (r=0.978), sulphate (0.665) and nitrate (0.68) in post monsoon.

Calcium content in the water samples ranged from 8.01 mg/L to 28.05mg/L as $CaCO_3$ in pre-monsoon; 16.03 mg/L to 40.08 mg/L in monsoon and 12.02 mg/L to 31.26 mg/L in post-monsoon 2017. Calcium is an important element among nutrients that increase bone mass and reduce fracture risk in humans. Ingestion of calcium ions exceeding the maximum allowable limit may cause health problems such as kidney stones, Hyper/hypocalcaemia, metabolic alkalosis, and renal insufficiency in those prone to the milk-alkali syndrome [11]. In human, hypocalcaemia causes coma and death if serum calcium level rises to 160 mg/L [12]. The results reveal that the concentration of calcium in water samples studied are below the permissible limit (75mg/L) of water quality standards [13]. The concentration of average value with 95% CL was found to be 19.82±5.26 in pre monsoon, 29.48±6.71 in monsoon and 19.86±4.89 in post monsoon seasons respectively. Calcium showed negative correlation with iron in premonsoon (r=-0.441), monsoon (r=-0.151) and post monsoon (r=-381) seasons, and positive correlation with all other parameters.

In the present study, during the pre-monsoon season, the magnesium concentration in bore well water varied from 0.97mg/L to 6.33 mg/L. The monsoon results varied from 2.54 mg/L to 23.87 mg/L. In post-monsoon, it is between 0.97mg/L to 11.2 mg/L. The permissible limit of magnesium in drinking water is 30 mg/L, and in all the well water samples studied the Mg content are below the permissible limit. Magnesium salts are soluble than calcium, but they are less abundant in geological formations. A low amount of Mg will result in health problems like hypertension, coronary heart disease, type 2 diabetes mellitus, and metabolic syndrome [11]. The permissible limit of magnesium in drinking water is 30 mg/L, and in all the well water samples studied the Mg content are below the permissible limit. The concentration of average value with 95% CL was found to be 3.56±1.12 in pre monsoon 6.89± 3.79 in monsoon and 3.28±1.73 in post monsoon seasons. Magnesium showed negative correlation with iron (r=-0.462) in pre monsoon, sodium (r=-0.118) in monsoon and sodium (r=-0.098), potassium (r =-065), phosphate (r =-119) in post monsoon seasons respectively.

The concentration of sodium in bore well samples varied from 49 mg/L to 65.9 mg/L during pre-monsoon, 17.7 mg/L to 88.1 mg/L in monsoon and 33 mg/L to 106.1 mg/L in post-monsoon. According to the standards for drinking water quality, the desirable limit of sodium in drinking water is 200mg/L. The study found that the sodium content in all the samples are within the standard permissible limit. A high range of sodium could be attributed to the leaching of solid wastes containing sodium salts. Sodium occurs in lower concentrations in freshwater than calcium and magnesium. The major sodium sources in water are sodium-bearing rock minerals, seawater intrusion, sewage effluent, leachates from landfills, and industries. Dissolution of salts in soil, silicate weathering, evaporation, anthropogenic activities, agricultural activities, and poor drainage conditions raise sodium concentration in groundwater [14]. The concentration of average value with 95% CL was found to be 51.18±10.32 in pre monsoon 46.96±22.37 in monsoon 58.1±21.23 in post monsoon seasons respectively. Sodium showed negative correlation with iron (r=-0.308) in pre monsoon, phosphate (r=-0.7) and iron (r=-498) in post monsoon respectively. All other parameters showed positive correlation with sodium.

The potassium (K^+) in well water samples in the study area varied from 9ppm to 55.5 ppm in pre-monsoon, 6.2 ppm to 19.8 ppm in monsoon 5.2 mg/L to 17.1 mg/L in post monsoon. Most potable groundwater contains less than 10 ppm of potassium and commonly ranges between 1 and 5 ppm [15]. Out of 36 water samples analyzed in the present study, majority of well water samples in the study (80 %) showed potassium content above 10 ppm. Potassium is relatively immobile in soil and subsoil. Consequently, the spreading of manure, slurry, and inorganic fertilizers are significantly increasing the potassium concentration in Groundwater [16]. Increased exposure to potassium may significantly affect people with kidney disease, heart disease, coronary artery disease, hypertension, diabetes, and adrenal insufficiency [13]. The concentration of average value with 95% CL was found to be 26.94±11.02 in pre monsoon, 12.62±3.76 in monsoon and 10.29±3.10 in post monsoon. The potassium showed negative correlation with iron (r=0.-494) in pre monsoon, monsoon (r=-0.057) and post monsoon (r=-0.353). All other parameters showed positive correlation with potassium.

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The concentration of nitrates in well water samples during pre-monsoon ranged from 7.92 mg/L to 33.44 mg/L, 12.76 mg/L to 32.12 mg/L in monsoon and 10 mg/L to 24 mg/L in post-monsoon, 2018 respectively. Nitrogen is the most abundant element in the atmosphere and can be found in many forms. During rain, gaseous nitrogen interacts with water to increase the nitrate and ammonium ions concentration. These ions enter groundwater by infiltration of rainwater to the shallow groundwater. In normal groundwater, nitrate concentration is below 2mg/L, and its concentration gradually increases due to anthropogenic activities [17]. The present study revealed that nitrate concentration in all the water samples are above 2mg/L and are within the standard permissible limit (45mg/L) prescribed by BIS. It may be due to wastewater leaching with organic nitrogen compounds from sewage farms and septic tanks [18]. High nitrate levels in waters used for drinking will render them hazardous to infants as they induce the "blue baby" syndrome (methaemoglobinaemia). The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite, which reacts with blood haemoglobin to cause methaemoglobinaemia. The concentration of average value with 95% CL was found to be 20.73±6.54 in pre monsoon, 19.82±3.79 in monsoon and 18.41±2.92 in post monsoon. The nitrate showed negative correlation with iron (r=0.-510) in pre monsoon, phosphate (r=-068) and iron (r=-0.082) in monsoon and phosphate in post monsoon (r=-0.218). All other parameters showed positive correlation with nitrate.

The sulphate content in the well water samples collected during pre-monsoon ranged from 26 mg/L to 50 mg/L, 25 mg/L to 42 mg/L in monsoon and 14 mg/L to 37 mg/L in post-monsoon respectively. According to BIS, the standard desirable limit of sulphate content in drinking water is 200mg/L. The present study showed that the sulphate content in all the well water samples are within the desirable limit of drinking water quality standards. The concentration of average value with 95% CL was found to be 36.33±6.68 in pre monsoon, 35.83±3.75 in monsoon and 28.16±4.76 in post monsoon. The sulphate showed negative correlation with iron (r=0.-355) in pre monsoon, monsoon (r=-0.117) and phosphate (r=-0.342) in post monsoon. All other parameters showed positive correlation.

The concentration of phosphates in well water samples showed a range of 0.09 mg/L to 0.195 mg/L during pre-monsoon, 0.02 mg/L to 0.03 mg/L in monsoon and 0.05 mg/L to 0.142 mg/L in post-monsoon. Phosphate concentration in most natural groundwater is less than 0.1 mg/L [19]. In the present study, it was found that out of 36 samples analyzed, nine samples (25%) in the pre-monsoon season showed values above 0.1mg/L. Higher concentrations of phosphates indicate pollution, and the major sources of anthropogenic phosphorus are sewage, detergents, agricultural effluents, and fertilizers [20, 21]. The concentration of average value with 95% CL was found to be 0.119±0.019 in pre monsoon, 0.027±0.002 in monsoon and 0.094 ±0.018 in post monsoon.

Heavy metal Content in Well water

Iron is an essential element in the metabolism of animals and plants. The concentration of iron in bore well water samples of the study area varied from 0.3 mg/L to 0.6 mg/L in pre-monsoon, 0.21 mg/L to 0.46 mg/L in monsoon season and 0.28 mg/L to 0.41 mg/L in post-monsoon season respectively (Figure 2). In all the water samples, Fe content is above the desirable limit (0.3mg/L) prescribed by WHO drinking water quality standards.

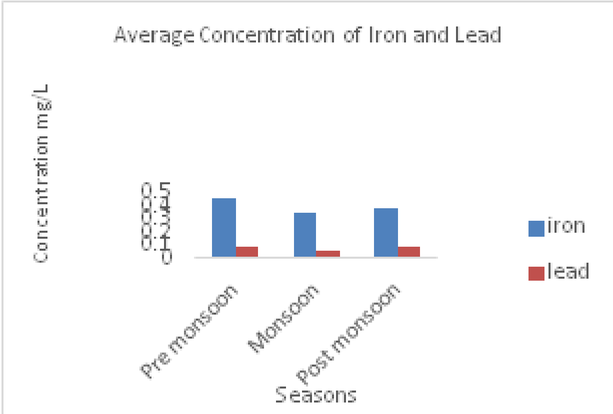

Figure 2: Seasonal variation in the concentration of Fe and Pb in Well water

Lead concentration in the bore well water samples showed a range of 0.0856 ppm to 0.1004 ppm in different seasons studied (Figure 2). The desirable limit of lead in drinking water is 0.05 ppm [5]. The results of heavy metal contents revealed that the concentration of iron and lead in the groundwater samples are above the permissible limit of WHO. The concentration of iron in groundwater will be higher under more reducing conditions due to the bacteriological degradation of organic matter, which leads to the formation of various humic and fulvic compounds [22]. In acidic conditions, the iron scrap present in the solid wastes may be dissolved and may leach to the groundwater during the rainy season.

Lead is an increasing problem in cities with older water systems. Water slowly corrodes the lead in municipal water systems which can cause a wide range of developmental difficulties for children and high blood pressure and kidney ailments in older and adults [23]. The present study results revealed that the Pb content in water samples are above the desirable limit. Lead has serious cumulative effects and can accumulate in bones, causing nausea, nervous and reproductive disorders, and cause kidney damage in humans [24]. Children may be more exposed to lead than adults due to their behavior, diet, and metabolic and physiological characteristics [25]. Besides, school-aged children spend many hours in and around school facilities that may expose them to potentially contaminated water sources by lead. Further, schools are high-risk environments due to their drinking water systems and users' complex nature [13]. For these reasons assessing lead contamination in the drinking water of school is very important.

Metal Index

Table 7 shows the results of Metal Index calculated by analyzing selected heavy metals. An MI value >1 is a threshold of warning, even in the case where C< MAC, for all the elements. From these data (table 7) it is clear that the metal index values are below 1.

Bacteriological Quality of Groundwater

The presence of microbial pathogens in groundwater poses a significant risk to public health (Ford, 2005). The bacteriological analysis of the drinking water samples from the schools collected in pre-monsoon, monsoon and postmonsoon seasons revealed that the water from the bore wells in the school premises is free from bacteriological contamination.

4. Conclusions

The present study on water quality of bore wells in the study area showed that most of the physico-chemical parameters are within the permissible limits of drinking water quality (BIS). Also, the drinking water from bore wells are free from bacterial contamination. The high concentration of iron recorded in the water samples may harm health and water supply structures and promote iron bacteria's growth. The high concentration of the toxic heavy metal lead in the water sample may cause adverse impacts like plumbism in children after long term consumption. Further research to identify the exact source of lead in the piped drinking water and at the source is crucial. The study recommends that the quality of drinking water, with special attention to lead should be monitored periodically and water purifier system must be maintained by cleaning the filter once in 6 months. Also the government should follow the standard environmental safeguard implementation practices in all educational institutions.

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Table 1: Statistical analysis for the physico-chemical characteristics of water samples during Pre-monsoon season

Parameter	pH	EC	TDS	DO	Cl	Ca	Mg	Na	K	Sulphate	Phosphate	Nitrate
AV	7.80	187.25	88.83	5.61	88.98	19.82	3.56	51.18	26.94	36.33	0.11	20.73
SE	0.26	25.70	11.54	0.51	17.47	2.39	0.51	4.69	5.01	3.03	0.008	2.97
SD	0.93	89.05	39.98	1.78	60.52	8.28	1.77	16.25	17.35	10.52	0.03	10.30
SV	0.86	7930.86	1599.0	3.19	3663.5	68.61	3.15	264.10	301.27	110.78	0.0009	106.26
Min	6.49	68.34	31.46	2.84	39.76	8.01	0.97	25.3	9	26	0.09	7.92
Max	9.1	353.7	161.4	8.53	204.48	29.65	6.33	65.9	55.5	60	0.19	33.44
Confidence level (95.0%)	0.5911	56.58	25.40	1.13	38.45	5.26	1.12	10.32	11.02	6.68	0.01	6.54

Table 2: Statistical analysis for the physico-chemical characteristics of water samples during Monsoon season

Parameter	pH	EC	TDS	DO	Cl	Ca	Mg	Na	K	Sulphate	Phosphate	Nitrate
AV	5.81	176.48	82.27	5.65	51.21	29.48	6.89	46.96	12.62	35.83	0.02	19.82
SE	0.33	26.19	12.32	0.34	8.76	3.04	1.72	10.16	1.71	1.70	0.001	1.72
SD	1.14	90.72	42.67	1.18	30.36	10.56	5.97	35.21	5.93	5.90	0.004	5.97
SV	1.31	8231.91	1821.46	1.40	922.26	111.60	35.67	1239.75	35.18	34.87	1.95E-05	35.67
Min	4.07	66.8	32.3	4.23	21.3	14.4	2.54	17.7	6.2	25	0.02	12.7
Max	7.64	323	149	7.82	88.04	40.08	23.8	88.1	19.8	42	0.03	32.1
Confidence level (95.0%)	0.72	57.64	27.11	0.75	19.29	6.71	3.79	22.37	3.76	3.75	0.002	3.79

Table 3: Statistical analysis for the physico-chemical characteristics of water samples during Post-monsoon season

Parameter	pH	EC	TDS	DO	Cl	Ca	Mg	Na	K	Sulphate	Phosphate	Nitrate
AV	4.77	398	210.25	5.56	37.01	19.86	3.28	58.1	10.29	28.16	0.094	18.41
SE	0.10	61.97	32.77	0.27	6.40	2.22	0.78	9.64	1.40	2.16	0.008	1.32
SD	0.35	214.6	113.5	0.96	22.20	7.70	2.72	33.42	4.88	7.49	0.028	4.601
SV	0.123	46091.82	12889.11	0.9369	492.84	59.32	7.42	1116.96	23.83	56.15	0.0008	21.17
Min	4.32	241	128	4	21.3	12	0.97	32.9	5.2	14	0.05	10
Max	5.46	701	370	7.2	68.1	31.2	11.2	106	17.1	37	0.14	24

Table 4: Correlation coefficient values among the physico-chemical parameters of water samples in Pre monsoon

Parameter	pH	Cond	TDS	DO	Chloride	Ca	Mg	Na	K	Sulphate	Nitrate	Phosphate	Fe
pH	1												
Cond	-0.744	1											
TDS	-0.776	0.977	1										
DO	-0.640	0.715	-0.737	1									
Chloride	-0.491	0.192	0.189	0.505	1								
Ca	-0.794	0.861	0.892	0.864	0.836	1							
Mg	-0.817	0.825	0.847	0.785	0.784	0.981	1						
Na	-0.534	0.772	0.824	0.849	0.749	0.803	0.676	1					
K	-0.798	0.879	0.887	0.727	0.777	0.943	0.953	0.688	1				
Sulphate	-0.755	0.842	0.886	0.929	0.879	0.944	0.881	0.885	0.882	1			
Nitrate	-0.328	0.817	0.735	0.710	0.725	0.644	0.555	0.739	0.618	0.680	1		
Phosphate	-0.706	0.817	0.832	0.631	0.547	0.891	0.908	0.615	0.847	0.749	0.539	1	
Fe	0.389	-0.564	-0.465	-0.298	-0.401	-0.441	-0.462	-0.308	-0.494	-0.355	-0.510	-0.324	1

Table 5: Correlation coefficient values among the physico-chemical parameters of water samples in Monsoon

Parameter	pH	Cond	TDS	DO	Chloride	Ca	Mg	Na	K	Sulphate	Nitrate	Phosphate	Fe
pH	1												
Cond	-0.834	1											
TDS	-0.837	1	1										
DO	-0.887	0.763	0.771	1									
Chloride	-0.245	0.211	0.213	0.047	1								
Ca	-0.613	0.809	0.813	0.649	0.826	1							
Mg	-0.423	0.193	0.195	0.567	0.302	0.101	1						
Na	-0.676	0.709	0.714	0.516	0.704	0.588	-0.119	1					
K	-0.905	0.928	0.933	0.877	0.996	0.843	0.341	0.706	1				
Sulphate	-0.907	0.931	0.937	0.876	0.982	0.847	0.298	0.707	0.987	1			
Nitrate	-0.723	0.677	0.687	0.749	0.766	0.674	0.518	0.551	0.803	0.830	1		
Phosphate	-0.122	0.351	0.331	0, 027	0.166	0.190	0.251	0.013	0.191	0.103	-0.068	1	
Fe	-0.113	0.074	0.061	0.032	-0.070	-0.151	0.165	0.212	-0.057	-0.117	-0.282	0.547	1

Table 6: Correlation coefficient values among the physico-chemical parameters of water samples in Post monsoon

Parameter	pH	Cond	TDS	DO	Chloride	Ca	Mg	Na	K	Sulphate	Nitrate	Phosphate	Fe
pH	1												
Cond	-0.246	1											
TDS	-0.243	1	1										
DO	0.623	-0.779	-0.779	1									
Chloride	-0.219	0.998	0.998	-0.762	1								
Ca	-0.332	0.952	0.952	-0.785	0.949	1							
Mg	-0.131	-0.101	-0.100	-0.065	-0.145	-0.188	1						
Na	-0.259	0.998	0.998	-0.781	0.997	0.951	-0.098	1					
K	-0.330	0.986	0.986	-0.845	0.978	0.952	-0.065	0.984	1				
Sulphate	-0.559	0.692	0.692	-0.831	0.665	0.7	0.085	0.683	0.798	1			
Nitrate	-0.553	0.716	0.716	-0.87	0.68	0.734	0.075	0.706	0.811	0.915	1		
Phosphate	-0.12	-0.691	-0.691	0.426	-0.683	-0.585	-0.119	-0.7	-0.666	-0.342	-0.218	1	
Fe	-0.412	-0.487	-0.487	-0.056	-0.519	-0.381	0.112	-0.498	-0.353	0.186	0.205	0.594	1

Table 7: Seasonal variations in the Mean Concentration of elements (μg/L) and Metal Index of Wellwater

	Element	Fe	Pb	Cr	Cd	As	Metal Index (MI)
	DL	1	1	0.3	0.1	1	
	MAC	50	10	50	5	10	
Pre Monsoon		430	87.7	6.5	46	<DL	0.007
Monsoon		320	60	6	41.5	<DL	0.005
Post Monsoon		350	51	5	36	<DL	0.005

*DL: Detection Limit *MAC: Maximum Allowable Concentration