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APPRAISAL OF WATER QUALITY OF SURFACE AND SUB-SURFACE SOURCES INRISHIKESH BY USING WATER QUALITY INDEX TECHNIQUE

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ABSTRACT

This study assesses the quality of surface and sub-surface water for drinking purposes. An attempt has been made to give an index of water collected from 27 sampling sites in the Rishikesh city of India. The water samples were analyzed for their physicochemical parameters like pH, turbidity, total hardness (TH), chloride (Cl^-), total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen (DO), and Chemical oxygen demand (COD), which indicate the suitability of surface and sub-surface water for different domestic and industrial uses. This study reveals that the majority of the water samples were found in the lower range of alkalinity limit (pH 7.2-7.75). The water quality index of water samples ranges from 44.18 to 77.63. The higher value of WQI has been found due to the presence of hardness and alkalinity in a water sample. The information obtained from this study may be helpful for the concerned, Govt. personnel, populace, NGO, shareholders and policymakers in planning suitable water management plans for civilization.

Keywords: *Water Quality Index (WQI), water quality parameters surface and sub surface, Physico-chemical parameters.*

INTRODUCTION

Water is undoubtedly the most valuable an essential constituent of environment and also crucial natural resource thathas marvelous role in the life of human being and it is directly linked with wellbeing of human, as well as an important tool of economic escalation, agriculture and industry. Ease of safe and adequate accessibility of fresh and safe water is a basic right, of human being, currently many association are helping to Indian government to achieved goal by the year 2030 (Luvhimbi et al. 2022). Now a day's fresh water ecosystems are the most scarce ecosystems in the globe and many Anthropogenic and natural activities happening in the environment at present hastened the process of humiliation from a number of sources such as chemical and pharmaceutical industries, liquidwaste released from residential and domestic area, oil refineries, coal and metal mining, ternary, electroplating, glass blowing, battery manufacture industries are globally degrading water quality (Yadav and Jamal, 2017, 2018;Duda et al., 2020). Due to mismanagement in the discarding of municipal solid waste of the society is also a cause of water pollution in the urban area (Chidichimo et al., 2020). Disposal of solid waste in sanitary landfill is the source of harmful leachate, if that is not properly discharged to the environment without apposite treatment, which contaminates the underground water quality and may be causes of many severe human health related issues in human,Terrestrial and aquatic animals (Przydatek and Kanownik, 2019;Tenodi et al., 2020; Akhtar et al., 2021; Chakravarty, and Gupta, 2021; Kumar, et al, 2022;Fadili, et al, 2022). As a result, mitigation of negative environmental impacts of landfill has become one of the most challenging issues of the world (Akoto, et al., 2021; Wijekoon et al. 2022). At present water pollution by several detrimental microbes is a worldwide problem. This is causes of many issues associated with human health (Pruss-Ustun et al., 2019). The following water quality parameters were chosen to evaluate the condition of the surface and subsurface water such as Temp, pH,Dissolved Oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS) chemical oxygen demand (COD) and chlorides. Water quality indexes were calculated for the water sample collected from surface and subsurface sources of water. In India, levels of water are constantly declining due to excessive use of water for different purposes such as domestic, industrial, and agricultural (Singh et al., 2020). More than 100 million communities in India are living in water harassed areas having water quality beyond the standards prescribed by BIS. Nowadays as per (WHO) report, globally more than 50 types of diseases are found in human due to poor quality of water, and 80% of diseasesand 50% of child deaths are associated to poor drinking water quality (Yadav and Jamal,2017; 2018, 2018A). Worldwide, around 850 million people cannot access clean and safe water, present time in India, around 2 billion inhabitants are using polluted water for drinking purposes, which contributes to around five lakh (5%) deaths annually from diarrhea, one of the top 10 killers in India, as shown in table 1.and major diarrhea contributing states are also shown in Figure 1. A survey conducted by National Family Health in India, shows that the occurrence of babyhood diarrhoea has increased from 9% to 9.2% from year 2016 to 2020 (Ghosh et al. 2021).

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The World Health Organization (WHO) claimed that up to 80% of all illnesses and diseases in the world are brought on by poor cleanliness, impure water, or a lack of access to water (WHO and UNICEF, 2017). Occurrence of numerous water- borne, water-washed, water-based, and water sanitation-related diseases is linked to the quality and accessibility of water and cleanliness to users, according to a World Bank analysis of 28 studies (Meride, and Ayenew, 2016). Every year, 1.8 million people, mostly children, in underdeveloped nations pass away from water-borne illnesses. Water- borne diseases create a high disease burden and widely impact on country's socio-economic growth (MDGRUN, 2015; Adelagun et al. 2021), all over the world. Assessment of physical water quality of water source can be accepted or rejected for domestic, irrigation or industrial purposes. Accordingly remedial measures can be planned to treat the contaminants (Sudarshan and Govardhan Das, 2012; Sundaraiah et al., 2013). The main aim of this study is to assess the surface and subsurface water quality for appropriateness to drinking uses around the study area. Fromthe last few decade, growth of old city and industrial activity, teeming infrastructures, resettlement of people from rural to urban area for better life style and jobs, proved very severe on the quality of surface and subsurface water resources. To assess the water quality by a single number a water quality index (WQI) has been suggested, which is based on an easy expression of the common water quality data for assess the effect of urban discharge on the water quality (Yadav and Jamal, 2018). WQI is a very useful and practical tool to classify surface waters or to assess pollution levels in a water body (Lermontov et al., 2011; Bakan et al., 2010). Moreover, WQI can identify the changing trends in water quality and it can facilitate comparisons between different sampling sites. The main principle of the study is to endow precious information for NGO, government personal and ecologist by properly describing the water quality status of surface and subsurface water (Wang at al. 2018; Yadav and Jamal, 2019).

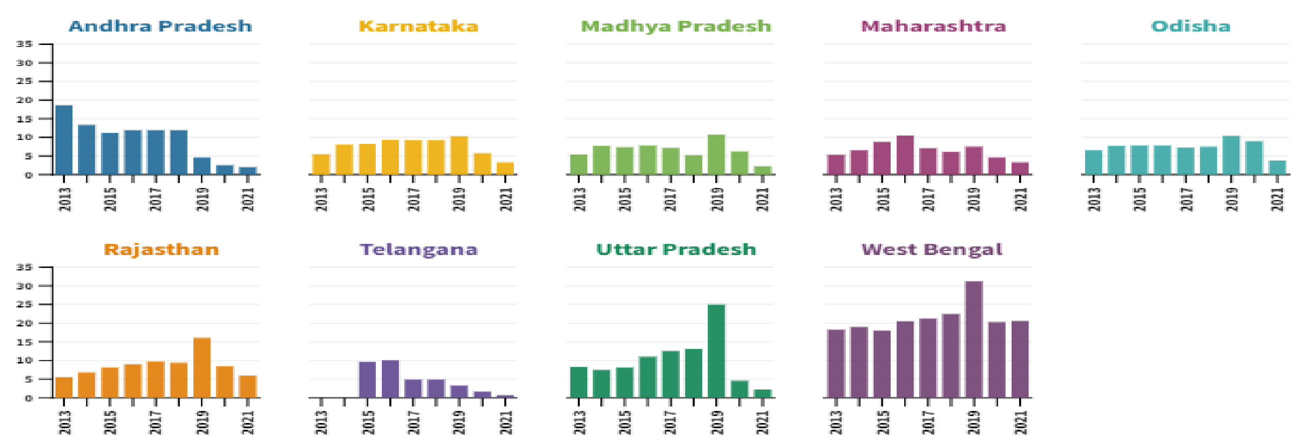
Table 1: Top ten causes of death in India

S NO.	Disease	% of total death	% change of 2005-2015
1.	Heart attack/ failure	16	+17
2.	Lung disease	10	+4
3.	Stroke/ brain hemorrhage	8	+7
4.	Bronchitis/ pneumonia	5	-23
5.	Diarrhea/ diseases	5	-32
6.	Tuberculosis	5	-31
7.	Diabetes	3	+35
8.	Chronic kidney disease	3	+21
9.	Preterm birth	3	-40
10.	Road injuries	3	-3

MATERIALS AND METHODS

Study area

The current study was conducted in pilgrimage town Rishikesh, regarded as one of the sanctified places for Hinduism, situated in district Dehradun, state of Uttarakhand. The city spreading 11.5 km^2 area and lies between: 30.103368°N 78.294754°E" (Fig.2).The area comprises usually an undulating terrain with low relief. The town is located in the Tehri Garhwal region of the northern Indian state of Uttarakhand. According to India's 2011 census, the population of city was 322,825 an average elevation of 340 meters. For present study twenty-seven sites were selected in Rishikesh city which includes eleven ground water sample and sixteen river water sample. Water samples were collected in clean and dry plastic gallon as per guide line of WHO, and temperature, pH, TDS, electrical conductivity and dissolved oxygen (DO) of water samples have been measured respectively from different sampling sites by using multiparameter instruments and analyses of other water quality parameters were carried out according to the BIS in the laboratory.



g.1: Major diarrhoea contributing states in India (Data from 2013 to 2021, number of cases in Lakhs)(Sources : National Health Profile)

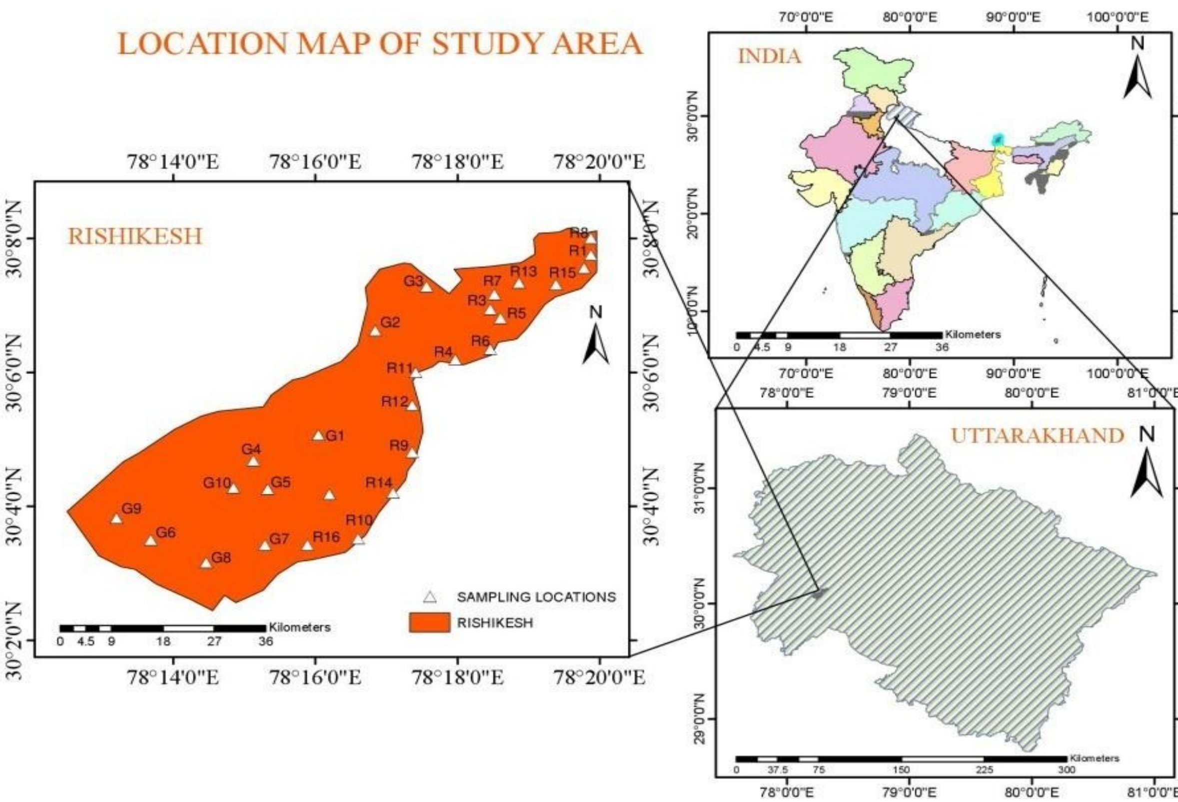


Fig.2:The location of study area and sampling sites.

Calculation of Water Quality Index (WQI)

The thought of water quality status categorization based on the level of water purity started Germany in 1848.The inclusive proposal based on selected 10 most common used water quality variables for ranking the water quality was developed by Horton (1965) in United States for ranking the water quality in single term, which show the combined consequence of the dissimilar water quality parameters of the entire quality of water. The numerous water quality characteristics were condensed by the WQI approach into a single, simple, and valuable mathematical quantitative. Due to simplicity of water quality index, later on adopted in various studies (Brown, 1970; Yadav and Jamal, 2018; Solangi et al. 2019; Hui et al. 2020; Sunar et al. 2020).

WQI approach will be also a very appropriate tool for bridging the overall water quality parameters in a single mathematical number for the concerned Govt., personnel, common people, NGO, stakeholders and policymakers for scheduling suitable water quality management plan for society (Tyagi et al., 2013; Yadav and Jamal, 2018).

The WQI were intended by using instruction suggested by national and international agencies such as BIS (BIS: 10500), (ICMR) and (WHO) .The Water Quality Index (WQI) for the surface and subsurface water body is assessed by using the technique of weighted arithmetic index. The important arithmetical associations are given as below:

$WQI = ((\Sigma w_i * q_i)/\Sigma w_i)$.

The formula used to compute WQI is:

$q_n = 100 \{ (v_i - v_o)/(s_i - v_o) \}$.where ,

v_n = Measured value of the ith parameter of the given sampling locations. v_o = Ideal value of ith parameter in pure water.

s_i =Standard permissible value of the ith parameter. Calculation of unit weight for the nth parameters. $W_n = (k/s_n)$. Finally, WQI was calculated as follows (Rana et al.,2018) $WQI = ((\Sigma w_i * q_i)/\Sigma w_i).)$

Table 2: Standards of Water Specified by Various Agencies

PARAMETERS	AUTHORITY	LIMIT
Temperature (°C)	WHO	25°C
pH	WHO/BIS	8.5
Turbidity (NTU)	WHO/BIS	5 NTU
TSS(mg/L)	WHO	500 mg/L
TDS (mg/L)	WHO	500 mg/L
EC (µS/cm)	ICMR	300 µS/cm
DO (mg/L)	WHO	5 mg/L
Hardness(mg/L)	WHO/BIS	200 mg/L
Acidity(mg/L)	WHO	200 mg/L
Alkalinity (mg/L)	WHO/BIS	200 mg/L
COD (mg/L)	WHO	10 mg/L
Chlorides (mg/L)	ICMR/BIS	250 mg/L

Table 3: Rating of water quality according to WQI

Water Quality Index Level	Grading	Water Quality Status	Explanation
0-25	A	Excellent	Water can be used for drinking purposes without any
			treatment.
25-50	B	Good	The water can be used for drinking after disinfection only
50-75	C	Poor	Primary treatment followed by disinfection is required
76-100	D	Very poor	Appropriate primary and secondary treatment are required before uses of water for drinking purposes
>100	E	Worst	In the lack of other water sources, water can be used for drinking with proper primary, secondary, tertiary and advanced water treatment

RESULTS AND DISCUSSIONS

Temperature

The average temperature of water samples of the study area was 19.9 °C and in the range of 18.4-20.9 °C. The temperature in this analysis was found to be within the WHO-permissible range of 30 °C.

pH Value

The pH value is a significant parameter for a quantitative measure of the acidity or basicity of water sample to make suitable decision water is acidic or alkaline in nature and plays a significant role in its suitability for household, industrial and agricultural purposes. As per CPCB the recommended pH value for drinking water are in the rages of 6.5-8.5 .The pH values of the water samples collected from study area ranges between 7.2–7.75. Which are lie in the range of CPCB limit.

Turbidity (NTU)

Turbidity in the study area was ranges from (2-6 NTU). The tolerable limit of turbidity is 5-25 NTU (WHO). The values Turbidity are found within the tolerable limit.

Total Suspended Solids (TSS)

The concentration of TSS was varies from 118.40 mg/l to 128.73mg/l.All the TDS values of river water samples were within the permissible limit as per IS: 10500.

Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) measures the total concentration of dissolved materials in water, including carbonate, chloride, and nitrate anions as well as calcium, magnesium, and potassium cations. TDS levels in the study area range from 44 to 495 mg/L.

Electrical Conductivity (EC)

Electrical conductivity (EC) depends on the temperature and ultimately measure the salinity. The values of Electrical conductivity (EC) of the study area vary from 66.7 to 750 µS/cm. The concentration of (EC) was found below the tolerable limits for irrigation and drinking water. The production of crops yield is typically impacted by the increased concentration of (EC) (Yadav and Jamal, 2018).

Dissolved oxygen (DO)

The concentration of Dissolved oxygen in surface and sub surface water sample varies between (5.3-14.4 mg/L. The allowable limit of (DO) as per (WHO) suggestion is 4 to 8 mg/L.

Hardness

The concentration of hardness in the surface and sub surface water was ranges from 8 to 27 mg/L. The acceptable limit of Hardness in drinking water as per recommendations of (WHO) is (500-1500) mg/L.

Acidity

Acidity in the study area was varied between 32 to 150 mg/L. All values of acidity found within the acceptable range. The acceptable limit of acidity as per (WHO) is 200mg/L.

Alkalinity

Alkalinity in the study area was varied between 42 to 496 mg/L. The acceptable limit of alkalinity is 200 mg/L (WHO). Alkalinity itself is not harmful to human beings but desirable limit of 100 mg/lit is always required for domestic supply of water. Few sampling sites are having excess concentration of alkalinity beyond the desirable limits.

Chemical oxygen demand (COD)

The most common use of COD is in quantifying the amount of oxidizable pollutants present in surface water. The higher value of COD in water shows the presence of organic matter in water samples. The ranges of COD in water sample were found as (3.6-7.1) mg/L. According to WHO recommendations (COD) is 10 mg/L is allowed in drink water.

Chloride

The values of Chloride content in water samples were found in the range of 10 to 71 mg/L. The minimum value of

Table 4: Water quality index of Rishikesh area

S. No.	Sample code	Name of sampling site	Water Quality Index	Classification
1.	G_1	NEAR IDPL POLICE STATION	64.82	Poor
2.	G_2	BHATTON WALA	71.03	Very poor
3.	G_3	MEERA NAGAR	71.65	Very poor
4.	G_4	NEAR RAILWAY STATION	67.37	Very poor
5.	G_5	NEELKANTH TEMPLE	63.36	Poor
6.	G_6	AKASH INST. INFO. CENTRE	69.96	Very poor
7.	G_7	NEAR SANJEEV FUELSTATION	64.49	Poor
8.	G_8	NEAR RISHIKESH CNG PUMP	68.20	Very poor
9.	G_9	S. B. PUBLIC SCHOOL	71.72	Very poor
10.	G_{10}	KHADRI ROAD	71.75	Very poor
11.	G_{11}	GHARHI SHYAMPUR	69.14	Poor
12.	R_1	LAXMAN JHULA	46.76	Moderate
13.	R_2	VEER BHADRA TEMPLE	59.92	Poor
14.	R_3	GANGA NAGAR	51.35	Moderate
15.	R_4	RAM NAGAR	55.30	Poor
16.	R_5	SHESH DHARA ASRAM	47.50	Moderate
17.	R_6	GANGA BARRAGE BRIDGE	50.46	Moderate
18.	R_7	SARWATMA DHAM ASRAM	57.35	Poor
19.	R_8	LAKKAD GHAT	69.87	Very poor
20.	R_9	RAM JHULA	44.16	Good
21.	R_{10}	PURNANAND GHAT	56.17	Poor
22.	R_{11}	TRIVENI GHAT	51.39	Moderate
23.	R_{12}	RISHIKESH GHAT	48.55	Moderate
24.	R_{13}	SWAMI NARAYAN GHAT	46.40	Moderate
25.	R_{14}	JANKI BRIDGE	48.55	Moderate
26.	R_{15}	NEEM BEACH	51.46	Moderate
27.	R_{16}	AIIMS	50.65	Moderate

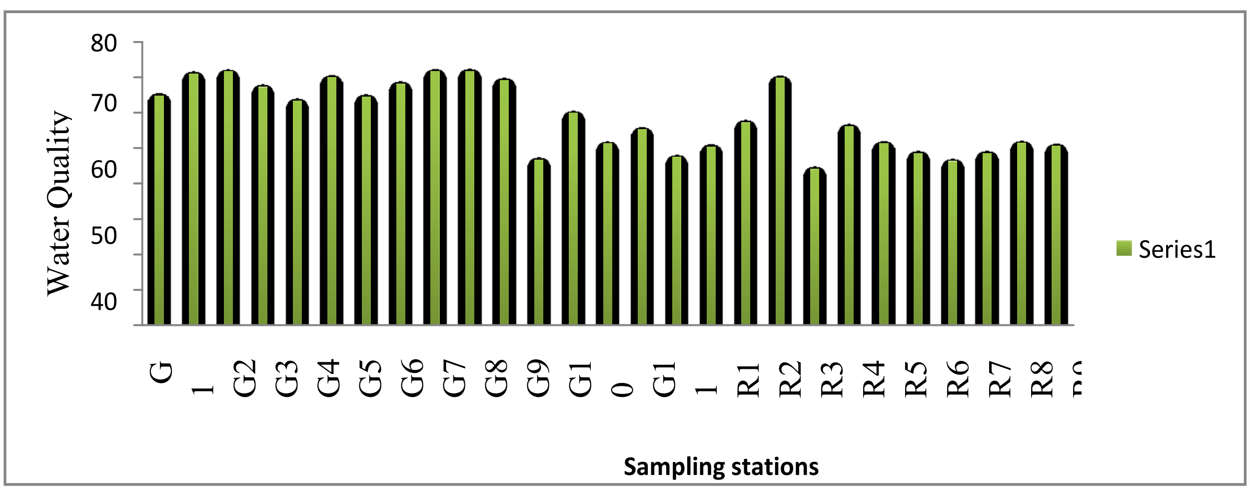


Fig.3. WQI at different of sampling location.

Chloride was observed 10 mg/L at a site of R1 (Lakshman Jhula). All the Chloride values of water samples were found within the acceptable range as per IS: 10500. The excess range of Chloride in water may be causes of Hypertension, salty taste, rusted plumbing, appliances, and fixtures, as well as blackening and pitting of stainless steel.

Water quality index (WQI)

WQI of River water and ground water samples varies from 44.17 to 77.65. The highest pollution level was found in the site G10, site G11 and site G7. Very poor water quality is found in sampling site R8, G2, G4, G6, G8, G9, G10, G11.Poor water quality is found in sampling site R2, R4, R7, R10, G1, G7.Moderate water quality is found in sampling site R_1, R_3, R_5, R_6, R_{11}, R_{12}, R_{13}, R_{14}, R_{15}, R_{16}. Good water quality is found in sampling site R_9. Shown in table 4.

Correlation analysis

The Correlation analysis results for the physico-chemical parameters of surface and subsurface water are shown in table5. pH is positive for TSS, TDS and DO and negative for EC, acidity, alkalinity and COD. Turbidity is positive for alkalinity and TDS. TDS is positive for EC, Hardness, acidity, alkalinity and COD and negative for DO. EC is positive for Hardness, acidity, alkalinity, COD and negative for DO. Hardness is positive for acidity, alkalinity and COD. Acidity is positive for alkalinity and COD. All the parameters showed a strong correlation with each other indicating the influence of the physico-chemical factors on the water quality.

Suitability of water for industrial purposes

To assess the appropriateness of water for industrial uses, Puckorius (PSI), Langelier (LSI) and Rayner (RSI), was considered. Table 6 show the statistical summary of the calculated indices for the quality of industrial water from the physicochemical parameters of surface and subsurface water samples.

CONCLUSIONS

Due to chronological, geographical, spiritual, political, and cultural reasons, Rishikesh city, India having a unique place in the world. In this study surface and subsurface water quality of Rishikesh city, India was evaluated by using water quality index technique. The WQI of surface and subsurface water samples were found in the range of 44.17 to 77.65. The higher value of WQI was found due to the presence of temperature, pH, total dissolved solids,

Table 5: Correlation analysis

PARAMTERS	TEMPERATURE	pH	TURBIDITY	TS	TSS	TDS	EC	DO	HARDNESS	ACIDITY	ALKALINITY	COD	CHLORIDES
TEMPERATURE (°C)	1												
pH	-0.2797	1											
TURBIDITY (NTU)	0.3490	-0.4709	1										
TS (mg/L)	0.3975	-0.3281	-0.0301	1									
TSS(mg/L)	-0.3143	0.5968	-0.4928	0.2849	1								
TDS (mg/L)	0.5557	1.0000	0.4638	0.3447	-0.8016	1							
EC (µS/cm)	0.5557	-0.7891	0.4638	0.3447	-0.8016	1.0000	1						
DO (mg/L)	-0.5262	0.6728	-0.4375	- 0.3320	0.7094	-0.9018	-0.9018	1					
HARDNESS(mg/L)	0.4203	-0.4369	0.0815	0.0692	-0.4970	0.5299	0.5299	-0.5163	1				
ACIDITY(mg/L)	0.2986	-0.5677	0.3719	0.1493	-0.6503	0.7299	0.7299	-0.6194	0.7071	1			
ALKALINITY (mg/L)	0.3742	-0.6052	0.7531	0.0999	-0.6472	0.6961	0.6961	-0.6835	0.3139	0.7004	1		
COD (mg/L)	0.2561	-0.5424	0.0501	0.3016	-0.4887	0.6667	0.6667	-0.4888	0.1928	0.4508	0.4336	1	
CHLORIDES (mg/L)	0.4147	-0.6752	0.4774	0.0875	-0.8385	0.8757	0.8757	-0.8312	0.4947	0.6604	0.6934	0.4897	1

Table 6: Classification of water quality for industrial use

S .No.	RSI	Inference (Ryznar 1944)	RSI	Inference (Carrier 1965)
1.	5.5	Heavy scale will form	4–5	Heavy scale
2.	5.5–6.2	Scale will form	5–6	Light scale
3.	6.2–6.	8 No difficulties	6–7	Small scale or corrosion
4.	6.8–8.5	Water is aggressive	7–7.5	Corrosion significant
5.			7.5–9	Heavy corrosion

Table 7: Summary of the calculated indices of the water samples

INDEX	RIVER WATER		GROUNDWATER	
	Mean	Result	Mean	Result
PSI	8.53353	Driving force to corrosionexists.	2.0515625	The water tends to encrusting.
LSI	-16.39572	Tendency to be corrosive.	-16.6500625	Tendency to be corrosive.
RSI	3.99894	Strongly encrusting	4.1056875	Strongly encrusting

turbidity, TSS, EC, Hardness, Acidity, Alkalinity, COD and chlorides, were acknowledged as dangerous polluting in water sample. Water qualities of some sampling stations are not suitable for drinking purpose without suitable treatment. The highest pollution level was found in the site G_{10}, site G_{11}. 26% water sample were found in poor categories, 33 % water sample were found in very poor categories, 37 % water sample were found in moderate categories and only one% water sample was found in good categories. The outcomes and recommendation of this study can be used by the governmental authorities, NGO and regulatory authority for certification of suitable management strategies for framing the useful water quality management strategy to combat the contamination of water resources surrounding the study area.

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