ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 11, Iss 10, Dec 2022

MULTIVARIATE STATISTICAL ANALYSIS OF WATER QUALITY OF WATER RESOURCES OF RISHIKESH BY USING WATER QUALITY INDEX TECHNIQUE

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Abstract

Globally, the natural water quality of water resources is degrading due to human interference. To evaluate the water quality of a region, it is crucial to comprehend the interaction between human activities and its different uses for different purposes. In this study, an attempt has been made to give an index of water samples collected from the holy river Ganga at twenty-five sampling stations in the yoga city of Uttarakhand, India. The water samples collected from different monitoring locations were analysed for their physicochemical parameters like pH, turbidity, total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen (DO), and biochemical oxygen demand (BOD), which specify the appropriateness of surface and sub-surface water for different domestic, commercial, agricultural, and industrial uses. This study reveals that the majority of the water samples were in the lower range of the alkalinity limit (pH 7.11–8.48). The range of the water quality index for the samples varied from 44.17 to 77.63. The higher values of WQI were seen due to the concentrations of nitrate, hardness, and sulphate in the water sample. According to the study's findings, many sites' Ganga River water can be used for residential and agricultural reasons; however, before consumption, safeguards and rigorous measures are required. The obtained results of this study may be extremely supportive to government officials, the general community, non-governmental organizations, shareholders, and policymakers in developing an appropriate water management strategy for society.

Keywords: Water Quality Index (WQI), Rishikesh, Physico-chemical parameters, GIS integration.

Introduction

Today's clean, harmless, and sufficient availability of freshwater is of utmost significance to human existence and the continued existence of all living components in the environment, as well as an important tool of economic escalation. There are now, internationally, a number of issues allied to water quality that cause many human health-associated problems (Yadav and Jamal, 2015; 2016; Pruss-Ustun et al., 2019). The World Health Organisation states that up to 80% of all diseases and illnesses around the

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world can be caused by bad sanitation, unclean water, or a lack of access to clean water (WHO 1997). According to a World Bank analysis of 28 studies (Ayenew, 2016), the 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. The holy river Ganga is a major perennial river of the country and also has great symbolism and status in Hinduism. It is the major river in the world by releasing discharge and originates from the Himalayas in the Indian state of Uttarakhand and flows through the north Indian Gangetic plain, covering a 2525 km2 catchment area and finishing the journey into the Bay of Bengal (Kamboj & Kamboj, 2019). The present study was taken to assess the quality of water for different favourable uses in the river Ganga, which sustains local and agricultural effluent all around the year in a very large part of the motherland. Rivers are also liable for maintaining or recharging groundwater aquifers(Ghalib & Sogut, 2014; Kamboj & Kamboj, 2019). The water chemistry of the riverine flora and fauna depends upon rich lithological characteristics, the evaporation process, and niche ecological parameters. The present study aimed to determine the water quality of the Ganga at Rishikesh, where millions of pilgrims come throughout the year and enjoy rafting. Present time due to industrialization and urbanisation in recent times. The Holy River Ganga is facing a lot of problems in the whole country, including Rishikesh also. The Water Quality Index (WQI) is a mathematical tool to freshwater is of utmost significance to human existence and the continued existence of all living components in the environment, as well as an important tool of economic escalation. There are now, internationally, a number of issues allied to water quality that cause many human health-associated problems (Yadav and Jamal, 2015; 2016; Pruss-Ustun et al., 2019). The World Health Organization states that up to 80% of all diseases and illnesses around the world can be caused by bad sanitation, unclean water, or a lack of access to clean water (WHO 1997). According to a World Bank analysis of 28 studies (Ayenew, 2016), the 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. The holy river Ganga is a major perennial river of the country and also has great symbolism and status in Hinduism. It is the major river in the world by releasing discharge and originates from the Himalayas in the Indian state of Uttarakhand and flows through the north Indian Gangetic plain, covering a 2525 km^2 catchment area and finishing the journey into the Bay of Bengal (Kamboj & Kamboj, 2019). The present study was taken to assess the quality of water for different favorable uses in the river Ganga, which sustains local and agricultural effluent all around the year in a very large part of the motherland. Rivers are also liable for maintaining or recharging groundwater aquifers (Ghalib & Sogut, 2014; Kamboj & Kamboj, 2019). The water chemistry of the riverine flora and fauna depends upon rich lithological characteristics, the evaporation process, and niche ecological parameters. The present study aimed to

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determine the water quality of the Ganga at Rishikesh, where millions of pilgrims come throughout the year and enjoy rafting. Present time due to industrialization and urbanization in recent times. The Holy River Ganga is facing a lot of problems in the whole country, including Rishikesh also. The Water Quality Index (WQI) is a mathematical tool to represent a large water quality dataset in a single number (Tambuk, 1999) for assessing the quality of water for human consumption (Asadi, Vuppala, & Anji, 2007; Hoseinzadeh, Khorsandi, Wei, & Alipour, 2014). It serves as the most useful tool for simple appreciation and communication of information regarding water quality (Batabyal and Chakraborty, 2015; Kamboj & Kamboj, 2019). WQI values are dependent upon the choice of water quality parameters and the conversion of raw data to a common simple scale. The main aim of the present research paper is to assess the level of pollution in the Ganga River using the WQI method.

Materials and Method

Study area

The study area is situated in pilgrimage town and yoga centre of Rishikesh, district Dehradun,Uttarakhand and it is also regarded as one of the hallowed places for Hinduism. The city spreading 11.5 Km^2 area and expanded from 30°072 latitude in the North to 78°192 longitude in the East. (Figure 1).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 records, the population of city was 322,825 an average elevation of 340 m. For present study twenty five sites were selected in Rishikesh city as per the guidelines of BIS which includes eleven ground water sample and sixteen river water sample.

Collection of Water Samples

During water sampling a total of 25 water samples were collected from the Rishikesh (Fig.1) in pre-cleaned and dry polyethylene bottles of capacity two liters treated with 5% conc. HNO_3 before water sampling at the depth of 15-20 cm below the surface water. A total of eight physicochemical parameters were being analyzed in the departmental laboratory for assessing the quality of surface

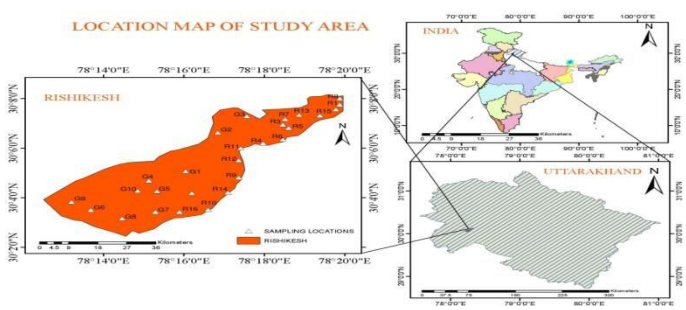

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Fig. 1: The location of study area and sampling sites.

In this study, calculation of water quality index was based on eight important physico-chemical parameters. The WQI calculated using the different standards of drinking water quality recommended by WHO, BIS and ICMR.

Table 1: Standards of Water Specified by various agencies

Parameters	**Authority**	**Limit**	**Parameters** in (mg/L)	**Authority**	**Limit**
Temp. (°C)	WHO	25°C	DO	WHO	5 mg/L
pH	WHO/BIS	8.5	Hardness	WHO/BIS	200 mg/L
TUR. (NTU)	WHO/BIS	5 NTU	Acidity	WHO	200 mg/L
TSS(mg/L)	WHO	500 mg/L	Alkalinity	WHO/BIS	200 mg/L
TDS (mg/L)	WHO	500 mg/L	COD	WHO	10 mg/L
EC (µS/cm)	ICMR	300 µS/cm	CHLORIDES	ICMR/BIS	250 mg/L

The water quality index is a numeric expression and it provides a single number that represents overall water quality at a definite position. The main purpose of the (WQI) is to reduce a set of water quality data in an instructional way. Water quality index was calculated by using the following following steps (Chandra et al, 2017; Yadav and Jamal, 2018; Kamboj & Kamboj,2019; Mohammad and Fatima, 2020)

Step 1: Assortment of data of various physico- chemical water quality parameters.

Step 2: Determination of proportionality constant " K " value using formula $k = (1/(1/\sum si))\ n$ i=1 where "si" is standard permissible for nth parameter.

Step 3: calculate quality rating for nth parameter (q n) where there are n parameters

WQI = ((Σw i* q i)/Σ w i).

This is calculated using formula:

q n=100 { (v i-v o)/(s i -v o)}.

where ,

v n = Measured value of the ith parameter of the given sampling station.

v o= Ideal value of ith parameter in pure water.

s i=Standard permissible value of the ith parameter.

Step 4: Calculate unit weight for the nth parameters. Wn=(k/s n).

Step 5: Calculate Water Quality Index (WQI) using formula,

WQI = ((Σw i* q i)/Σ w i).

Table 2:Water quality index and its corresponding water quality status for different uses (Brown et al. 1972;Singh and Kamal, 2014;Yadav and Jamal,2018;Yadav and Jamal, 2019; Tiwary et al. 2019)

S. No	WQI values	Classification of categories	Grades	Possible different Uses
1.	0-25	Excellent	A	Suitable for drinking, irrigation and for different industrial activities

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2.	26-50	Good water	B	Suitable for domestic, irrigation and for different industrial activities.
3.	51-75	Fair water	C	Suitable for irrigation and for different industrial activities
4.	76-100	Poor water	D	Suitable for agricultural uses
5.	101-150	Very poor	E	Suitable for limited use for irrigation
6.	Above 150	Unhealthy for utilization	F	Suitable treatment necessary before utilization

Results and discussion

Temperature

The average temperature of water samples collected from the study area were varies from 18.4 °C to 20.89 °C. The temperature in this assessment was found to be within the WHO-permissible range of 30 °C. and its spatial distribution are shown in Fig.2.

pH Value

pH value generally shows the degree of the acidity or basicity of water solution to make a decision for water is acidic or alkaline in nature and plays an significant role in its aptness for domestic, industrial and agricultural purposes. As per the recommended CPCB and BIS , pH value for drinking water are in the ranges of 6.5-8.5 .The pH values of the water samples collected from study area varies between 7.11-8.48 and its spatial distribution are shown in Fig.3 Which are found in the permissible limit of pH as per BIS.

Dissolved oxygen (DO)

Dissolved oxygen is an essential parameter in water quality in the assessment of water quality parameters Dissolved oxygen play a very important role, which also reflects the physical and biological process prevailing in the water which shows the degree of pollution in any water bodies. The average concentration of concentration of Dissolved oxygen in sample varies between (5.3-14.4) mg/L and their spatial distributions are shown in Fig.4. The allowable limit of (DO) as per (WHO) suggestion is 4 to 8 mg/L.

Electrical Conductivity (EC)

Electrical conductivity (EC) depends on the temperature and eventually measure the salinity and its limit depends on concentration of dissolved ions present in a water sample. The values of Electrical conductivity (EC) of the study area were found in the range of 68.83 to 749,95 µS/cm and its spatial distribution are shown in Fig.5. In the study area the concentration of (EC) was

ISSN PRINT 2319 1775 Online 2320 7876

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found below the acceptable limits for irrigation and drinking water. The higher concentration of (EC) normally disturbed the crops yield (Yadav and Jamal, 2016; Yadav and Jamal, 2018).

Hardness

The presence of hardness in water sample is primarily caused by the presence of cations such as calcium and magnesium and anions such as carbonates, bicarbonates, and chloride in water and its concentration in water sample were found in the range between (8-26.99) mg/L and its spatial distribution are shown in Fig.6. The tolerable limit as per (WHO) recommendations of Hardness is (150-300) mg/L) (WHO, 2011).

Total Dissolved Solids (TDS)

Total Dissolved Solids is direct measurement of dissolved particles present in the water sample such as calcium, magnesium, and potassium cations and carbonate, chloride, and nitrate anions. The average concentration of TDS in study area varies from 44.11 to 494.11 mg/L and its spatial distribution are shown in Fig.7 According to the BIS the desirable limit of TDS is 500 mg/l. and found within the allowable limit (Kamboj et al.2016).

Turbidity

Turbidity (TUR.) in the study area was ranges from (2-6.3 NTU). The acceptable limit of turbidity is 5-25 NTU (WHO).All values of Turbidity nearly found in the range of limits.

Magnesium (Mg^{2+})

The concentration of Magnesium ion of groundwater sample ranges from (3-18) mg/L. The permissible limit of magnesium as per (WHO) recommendations is (30-150) mg/L.

Calcium (Ca^{2+})

The concentration of calcium ion in surface and sub surface water in the study area was ranged between (24-668) mg/L. The usual calcium limit as per (WHO) recommendations is (75-200) mg/L.

Magnesium (Mg^{2+})

The concentration of Magnesium ion of groundwater sample ranges from (3-18) mg/L. The permissible limit of magnesium as per (WHO) recommendations is (30-150) mg/L.

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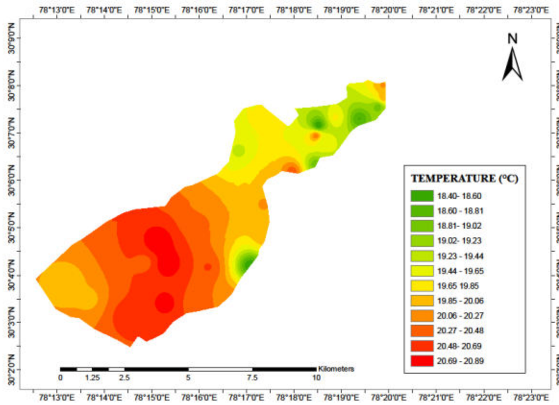

Figure 2: Spatial distribution of (Temp.)

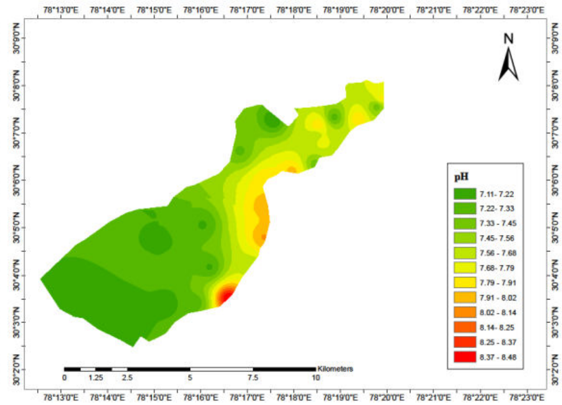

Figure 3: Spatial distribution of (pH)

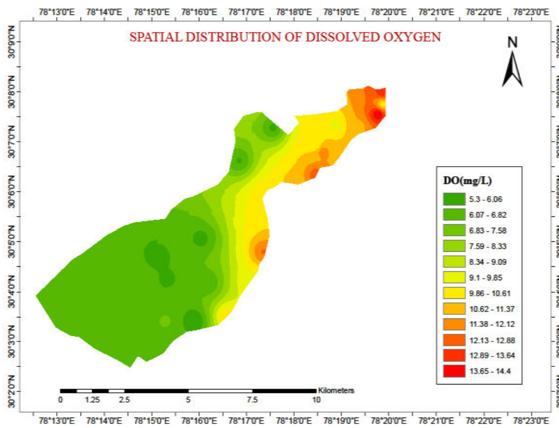

Figure 4: Spatial distribution of (DO)

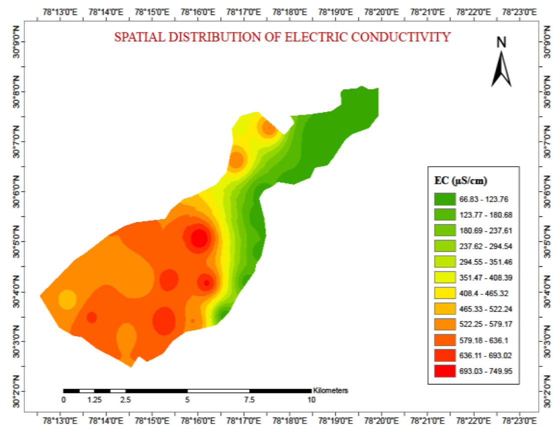

Figure 5: Spatial distribution of (EC)

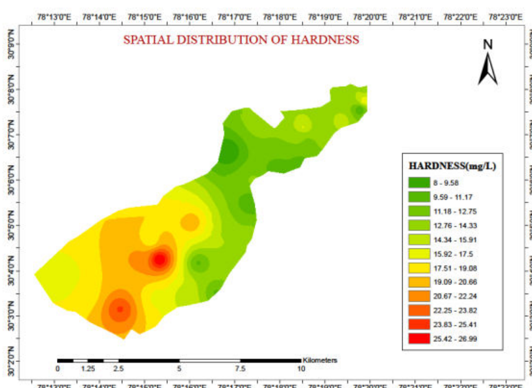

Figure 6: Spatial distribution of Hardness

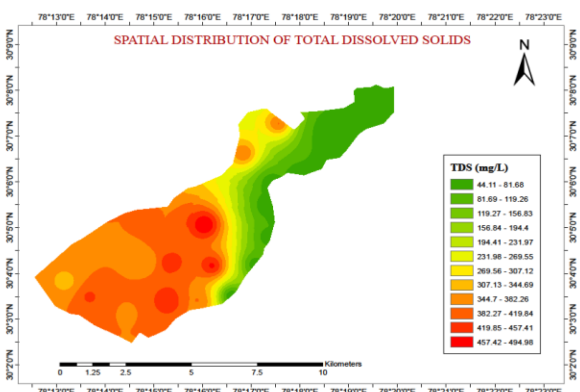

Figure 7: Spatial distribution of (TDS)

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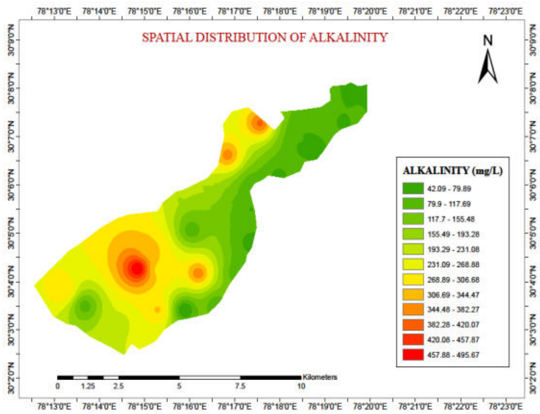

Figure 8: Spatial distribution of Alkalinity

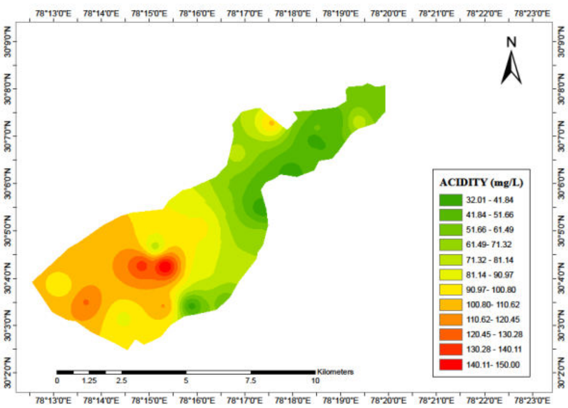

Figure 9: Spatial distribution of Acidity

In this study 24% of the water samples were ‘‘poor’’,36% were, ‘very poor’’, 36% were fall in “moderate” categories and only 0.04% water sample fall in “good’’ categories (Table 3). A high concentration of physicochemical parameters such as TDS, EC, and TH, the ions such as Cl- and Na+ contributed to higher values of water quality index. The study data show the WQI of River water and ground water samples varies from 44.17 to 77.65. The higher value of WQI was found due to the presence of temperature, pH , total dissolved solids, turbidity, TSS, EC, DO, Hardness, Acidity, Alkalinity, COD, chlorides and sulphate, in main sump water sample. The higher value of WQI was found due to the presence of temperature, pH, total dissolved solids, turbidity, TSS, EC, DO, Hardness, Acidity, Alkalinity, COD, in water sample.

Table 3: WQI values of water samples

S.No.	River water Samples	WQI value	Classification
1.	Bhattonwala	77.63	Very poor
2.	Meera Nagar	71.65	Very poor
3.	Near Railway Station	67.37	Very poor
4.	Neelkanth Temple	63.37	Poor
5.	A.Inst. Inform. Centre	69.96	Very poor
6.	Near Sanjeev Fuel Petrol Pump	64.50	Poor
7.	Near Rishikesh CNG Pump	68.20	Very poor
8.	S.B Public School	71.73	Very poor
9.	Khadri Road	71.76	Very poor
10.	Gharhi Shyampur	69.15	Very poor
11.	Laxman Jhula	46.77	Moderate
12.	Veer Bhadra Temple	59.93	Poor
13.	Ganga Nagar	51.36	Moderate
14.	Ram Nagar	55.31	Poor

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15.	S.D Asram	47.50	Moderate
16.	Ganga Barrage Bridge	50.47	Moderate
17.	AIIMS	50.65	Moderate
18.	Lakkad Ghat	69.88	Very poor
19.	Ram Jhula	44.17	Good
20.	Purnanand Ghat	56.18	Poor
21.	Triveni Ghat	51.40	Moderate
22.	Rishikesh Ghat	48.55	Moderate
23.	Swami Narayan Ghat	46.41	Moderate
24.	Janki Bridge	48.56	Moderate
25.	Neem Beach	51.46	Moderate

Conclusion:

The calculated values of WQI range from 44.17 to 77.63, which show that 60% of water samples fall into the poor to very poor category, which shows its inappropriateness for drinking purposes. It can be concluded that the geological composition and different anthropogenic activities, such as the discharge of waste water and agricultural practises, are significantly influencing the quality of water. The analysis reveals that the various constituents in the water samples are within the prescribed limits. Some of the places where the water is below the permissible limit and in the doubtful category need special attention.

Acknowledgement:

The authors are especially thankful to the Head Department of civil engineering, Govind Ballabh Pant Institute of Engineering and Technology, for providing financial and technical support during the whole study period.

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