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Research Paper

Assessment of physicochemical parameters and water quality fluctuations in the Kosi River at Ramnagar, Uttarakhand, India.

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ABSTRACT: *This study evaluates the quality of groundwater in the Ramnagar area of the Kosi River, located in the Nainital district of Uttarakhand. The study uses geospatial, temporal, and statistical methods. Ramnagar city is the first point where the Kosi River meets the plain region after flowing through a hilly area. As the river enters the plain region, it undergoes significant changes in terms of geography, environment, and urbanization. A total of fifteen water quality parameters were measured in samples collected from five different sites during pre-monsoon (PRM) monsoon (MON), post-monsoon (POM) of the river including pH, electrical conductivity (EC), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), chloride (Cl^-), sulphate (SO_4^{2-}), nitrate (NO_3^-), fluoride (F^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), Cl^-, TDS and total hardness (TH) were measured at five sites across the study area during pre-, monsoon, and post-monsoon seasons in 2019. The concentration of parameters at each site is compared with their permissible limits recommended by the Bureau of Indian Standards (IS 10500: 2012) to assess their suitability for human drinking. Based on the physicochemical analysis, it can be observed that the majority of the water samples taken from the river are within the permissible limits recommended by the World Health Organization (WHO) for drinking purposes. Additionally, the calculated average Water Quality Index (WQI) values for PRM, MON, and POM are 37.53, 22.88, and 36.17 respectively, which fall under the excellent to good categories. Therefore, based on the WQI results, it can be inferred that the water of the Kosi River in the Ramnagar region is suitable for drinking and other domestic uses without any further treatment.*

KEYWORDS: *WQI, seasonal fluctuations, Physico-chemical parameters, river Kosi, Ramnagar*

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I. INTRODUCTION

Water contamination is a sensitive issue at present as it has caused numerous diseases and deaths worldwide. In India, water pollution is further intensified by rapid growth in industries, fast urbanization, and population growth, leading to increased discharge of effluents and pollutants into the environment [1], [2], [3], [4], [5], [6], [7], [8] that changes in their physicochemical parameters of drinking water. These changes can be harmful to both humans and animals, as they can cause diseases and toxic health effects if poor-quality water is consumed. Moreover, a decline in water quality can also affect the survival conditions of aquatic ecosystems. The permissible limits for various physical, chemical, and biological characteristics of water are set to ensure that it is safe for a specific purpose. However, the ever-increasing anthropogenic interventions have led to frightening levels of water pollution, as evidenced by multiple studies [2], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20]. Persistent consumption of contaminated water for irrigation leads to a decrease in soil quality, making it less productive or even inadequate for agricultural purposes [21] directly affecting human health. Therefore, it is highly important to regularly assess the quality of water to preserve and maintain the natural ecosystem [2], [22], [23], [24].

Rivers are an essential source of water for the growing human population. At the same time, rivers are the leading carriers and dumping sites for effluents, sewage, garbage, and other anthropogenic wastes. The waste discharged into the river adversely affects its water quality and renders it unfit for consumption and other human activities. As per the study, 70% of river water in India is unfit for human consumption [25]. The growing population and industrialization have further limited the access of prominent people to clean water. This pressing demand for water has compelled the scientific community to reassess the water quality of various sources to monitor and preserve these resources for future generations [2], [22], [23], [26]. In general, water quality assessment includes monitoring its physical, chemical, and biological dimensions with different parameters [27] . Water quality indices (WQIs) are tools used by researchers since the 1960s [28]. With increasing interest and understanding of water quality assessment, various WQI tools are being developed to present the change in the water quality of the water systems in a simple and understandable form [29]. As per the literature, nearly 30 WQI are used worldwide to monitor the water quality so that it gives relevant information to the water authorities and can be used for making future recommendations (e.g., [30], [31]).

The Kosi River is a major tributary of the Ram Ganga in Northern India. It originates from the spring source at Rudradhari (District Almora, Uttarakhand) and flows for 240 km, covering a catchment area of 3420 km^2 across the hill and plain terrain of Uttarakhand and Uttar Pradesh. Its longitude and latitude coordinates are 85°17" east and 27°47" north respectively. The Kosi River Basin includes significant areas such as Tota-aam and Garjiya Temple in Ramnagar (District Nainital), Kashipur (District Udham Singh Nagar), Dadiyal, Swar, Lalpur, and City Rampur. It merges with the Ramganga River near the village of Chamraul in the Rampur district of Uttar Pradesh.

"River Kosi serves as the primary source of water for the region and, along with its catchment area, forms a significant ecosystem for the hilly state of Uttarakhand. Rapidly increasing anthropogenic activities that extend from the origin to the basin of the river Kosi and the ever-growing population of the towns and cities along the river pose a challenge to the researchers assessing the water quality of the river Kosi. A wide range of parameters is used to give an accurate and up-to-date picture of the river's water quality. Unfortunately, an exhaustive literature review provides a grim picture on this front. Even after putting in sincere effort, our team could not find any reliable, authentic research work done on the assessment of WQI of the river Kosi in the past decade. The literature on studying the physicochemical parameters and water quality monitoring of the river is more than a decade old and based on very few parameters [32] and references therein). Our group, therefore, decided to determine the different physicochemical parameters of the river Kosi for one year by dividing it into pre-, during, and post-monsoon seasons and assessing its water quality based on the latest and most widely used WQIs.

II. STUDY AREA

The study area Ramnagar (Nainital), Uttarakhand, India, is located at the foothill of Himalaya between 29°20′13″N and 29°24′42″N latitudes and 79°04′15″E to 79°08′22″E longitudes [33]. In the North, it is surrounded by the Shivalik hills and the Gangetic plains in the South. The river Kosi flows west, whereas the river Gola flows east. Other remarkable rivers include the Dabka, Bor, Nihal, and Bhakra. This area has coarse soil and rocks on the northern side which is dominated by the hilly slope. The southern side of the region has alluvium, clay-rich marshes. During the Southwest Monsoon (June-September), the area receives an average yearly rainfall of 1925 mm [34]. The study of water quality assessment in Ramnagar is important because the river Kosi leave the hills and enters into the plain and the population density increases suddenly along the course of the river.

III. METHODOLOGY

III.1. Sampling

Five different sites (S1- S5) were selected for sampling based on location, environment, and land use activities. The details of the location of sampling are shown on the map (Fig. 1) and compiled in Table 1.

The water samples were collected and stored in 500 mL sterilized bottles as per the standard method American Public Health Association (APHA) 2017 [35], from March 2019 to February 2020 to observe seasonal variations in river water quality. The temperature of the water was also noted at the time of sampling. The time from March to May was taken as pre-monsoon season (PRM), June to September was taken as during monsoon (MON), and October to December as post-monsoon (POM) season based on the percentage of rainfall the region receives during these months. The analyses were performed based on twelve physicochemical parameters; pH, Turbidity, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), nitrate, chloride, sulfate, sodium, potassium, magnesium, and calcium in the laboratory per the standard guidelines [36].

III.2. Analytical Measurements

All tests were conducted in triplicate at the river site and the results were presented as mean values. Parameters with fluctuating nature, such as Turbidity, pH, and TDS, were measured at the sampling site using a Nephelometer (Model: PPC compact, Germany), a pH meter (PC-II, Hach, USA), and a digital TDS meter, respectively. Total hardness was measured using the EDTA titration method, and the concentration of specific ions was determined using the colourimetric technique with a DR 5000 Spectrophotometer (Hach, USA) and atomic absorption spectrometry with a Varian AA240FS spectrometer.

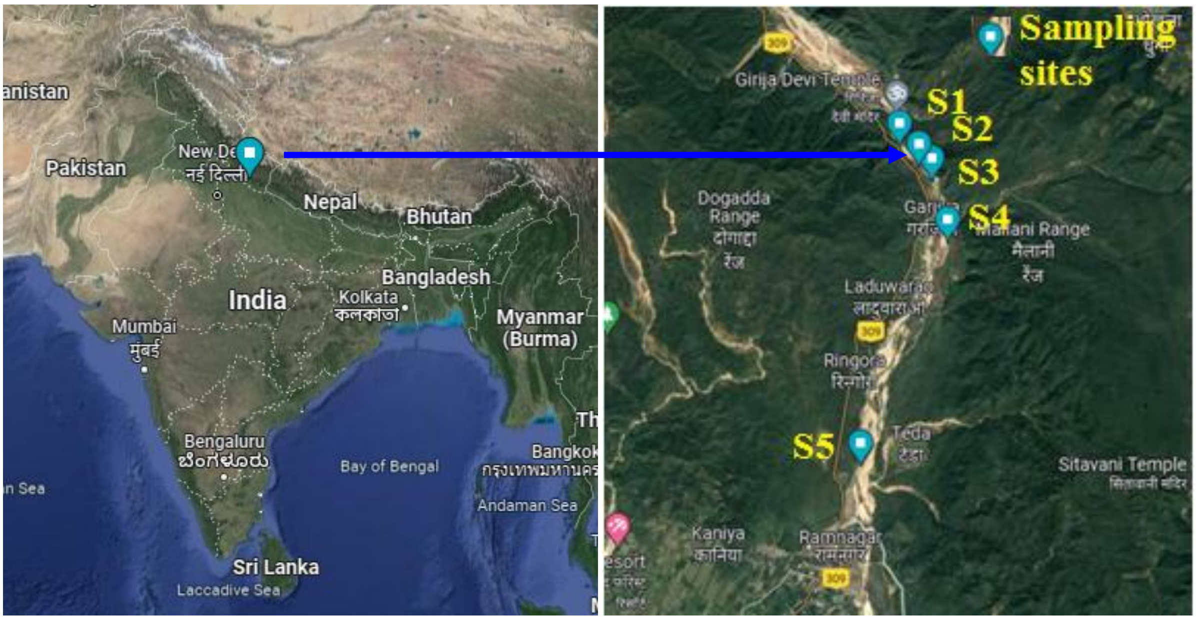

Fig. 1:
Google map of the study area and Location of river-water sample collection sites (Ramnagar, Nainital districts, Uttarakhand, India)

Table 1: Locations of sites from where water samples have been collected

No	Latitude	Longitude	Locality name
1.	29.48703	79.14205	Garjiya Bridge(Near Garjiya Temple)
2.	29.48219	79.14725	Kosi river (Near Garjiya Village)
3.	29.472767	79.13054	Kosi Canal (Near Post Office Dhikuli)
4.	29.41156	79.149589	Dhikuli Resort
5.	29.463968	79.149589	River Point (Garjiya road)

III.3. Water Quality Index

Assessing the quality of water is done using the Water Quality Index (WQI). In our study, we employed the Weighted Arithmetic Water Quality Index (WAWQI) to measure water quality. Below, we present the steps followed to calculate the WAWQI in brief below:

3.3.1 Weighted Arithmetic Water Quality Index (WAWQI)

The WAWQI was measured by following steps as mentioned [28]:

Step 1: Calculation of unit weight (Wi) for different parameters:

It was calculated by the following formula [37]:

$$W_i = K \sum \frac{1}{S_{Standard}} \quad (1)$$

Where K is a proportionality constant, that can be calculated by using the following equation: $K = \frac{1}{\sum_1^n \frac{1}{S_n}}$

(2)

According to the formula, unit weight has an inverse relationship with the recommended standard value (Standard) of the corresponding parameter.

Step 2: Calculation of quality rating scale (Q_i) for each parameter:

It was calculated for each parameter with the help of the following formula:

$$Q_i = \frac{(Q_{act} - Q_{ideal})}{(Q_{standard} - Q_{ideal})} \times 100 \quad (3)$$

Where, Q_{actual} = estimated concentration of i^{th} parameter in the analyzed water; Q_{ideal} = the ideal value of i^{th} parameter in pure water. It has a value 'zero' (except pH = 7.0 and DO = 14.6 mg L^{-1}) $S_{standard}$= Recommended standard value of i^{th} parameter

Step 3: Calculation of overall WQI:
It was calculated by adding the product of the quality rating of each parameter with the corresponding unit weight and taking the average.

$$WAWQI = \frac{\sum_{i=1}^{i=n} Q_i W_i}{\sum W_i} \quad (4)$$

The weighted Arithmetic Water Quality Index (WAWQI) method takes the maximum WQI as 100 and grades the water sample on a scale of 0-100 as per its WQI.

IV. Results and Discussion

IV.1 Physicochemical Parameters

This work shows seasonal variation of various parameters and WQI of five different sites of river Kosi (supplementary table-1). The determined water quality is represented in Table 2. The values of all parameters are compared with BIS standard 2012 and WHO standards 2011 and are shown by Mean, Standard deviation, Minimum, and Maximum (Table 2)**.**

Table 2: Various physicochemical parameters measured from Kosi River in Ramnagar region and their acceptable and permissible limits (10050: IS 2012)

Season	pH	Turbidity (NTU)	EC (µS/cm)	TDS (mg/l)	TH (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^{+} (mg/l)	Cl^{-} (mg/l)	NO_3^{-} (mg/l)	SO_4^{-} (mg/l)
Pre-monsoon	7.87	0.94	159.7	216.00	126.70	89.67	36.5	7.40	5.33	0.51	36.60
	7.77	0.637	198.3	221.00	127.00	85.33	38.00	7.13	4.67	0.53	36.30
	7.73	0.607	209.4	221.00	117.30	83.00	37.50	6.93	4.67	0.84	36.20
	7.80	0.603	208.6	222.70	114.00	82.00	40.20	7.20	4.67	0.86	36.50
	7.80	0.923	244.7	227.30	115.60	81.67	37.80	7.37	5.17	0.91	36.70
Avg.	**7.79**	**0.74**	**204.15**	**221.61**	**120.12**	**84.33**	**38.00**	**7.21**	**4.90**	**0.73**	**36.46**
Std.	**0.05**	**0.15**	**27.21**	**3.63**	**5.59**	**2.96**	**1.21**	**0.17**	**0.29**	**0.17**	**0.19**
Monsoon	7.47	1.02	166.1	254.50	133.25	98.83	18.90	7.63	5.14	0.72	36.03
	7.69	0.975	154.9	257.00	128.75	97.78	19.80	7.53	4.75	0.67	35.23
	7.55	0.825	161.3	248.25	123.75	98.85	17.10	7.23	4.58	0.72	34.40
	7.74	0.36	158.9	248.00	127.25	95.28	16.50	7.13	4.14	0.69	34.10
	7.72	0.325	171.6	255.25	128.00	98.48	18.40	7.15	4.15	0.77	34.80
Avg.	**7.63**	**0.69**	**162.58**	**252.67**	**128.24**	**97.84**	**18.14**	**7.33**	**4.55**	**0.71**	**34.92**
Std.	**0.11**	**0.29**	**5.79**	**3.79**	**3.05**	**1.34**	**1.20**	**0.21**	**0.38**	**0.03**	**0.68**
Post-Monsoon	8.03	0.14	165.47	250.67	145.33	109.13	13.90	7.00	4.63	0.61	31.03
	8.13	0.09	164.77	250.67	147.33	112.60	14.70	6.53	4.67	0.59	32.23
	8.00	0.1	163.67	250.67	144.67	106.53	13.70	6.70	4.13	0.68	33.70
	7.97	0.07	153.6	252.33	146.00	107.47	14.70	5.90	4.00	0.61	31.37
	8.03	0.10	154.5	250.67	148.00	106.73	15.00	5.87	4.00	0.73	30.57
Avg.	**8.03**	**0.10**	**160.40**	**251.00**	**146.27**	**108.49**	**14.40**	**6.40**	**4.29**	**0.64**	**31.78**
Std.	**0.05**	**0.02**	**5.23**	**0.66**	**1.24**	**2.25**	**0.51**	**0.45**	**0.30**	**0.05**	**1.10**
Acceptable limit	**6.5-8.5**	**1.00**		**500.00**	**200.00**	**75.00**	**30.00**	**20.00**	**250.00**	**45.00**	**200.00**
Permissible limit	**No relax**	**5.00**	**2000**	**2000.00**	**600.00**	**200.00**	**100.00**	**60.00**	**1000.00**	**No relax**	**400.00**

The pH value of water critically influences the solubility of minerals and the activity of important pathogens [38]. The lower value of pH of drinking water not only affects biochemical processes but also highly influences the solubility of minerals and the activity of important pathogens indirectly[11]. The average pH of these five sites ranges between 7.73-7.88 with an average of 7.79 (Std. = 0.05; table-2) during the pre-monsoon season (PRM) whereas, the average pH during monsoon (DM) varied in the range of 7.47-7.74 (Avg. = 7.63, Std. = 0.11) and 7.97-8.13 (Avg. = 8.03, Std. = 0.05) during post-monsoon (POM) season. A geological formation composed of $CaCO_3$ is a major cause of shifting in pH value towards the alkaline or acidic side of neutrality (e.g., [39], [40]). The above findings suggest that the pH level of the river water is slightly higher during the post-monsoon season as compared to the pre- and during-monsoon periods. However, all the pH values fall within the acceptable limit recommended by the World Health Organization (pH = 6.5-8.5). Therefore, it can be concluded that seasonal variations in the river water have a negligible impact on its pH level. The pH range of the river water is safe for human consumption.

Turbidity is another important parameter which determines the safety standard of water for drinking. The turbidity of water during PRM at different sampling sites was in the range of 0.60 to 0.94 NTU with an average of 0.74 NTU (Std. = 0.15). The turbidity shows a large variation (0.33-1.02 NTU; Avg. = 0.69 NTU; Std. = 0.29) in the DM season. On the other hand, the turbidity varies from 0.070 to 0.140 NTU (Avg. = 0.10; Std. = 0.02) in the POM season. Turbidity is a factor that affects the transparency and clarity of water, and it is responsible for altering the colour of the water. The presence of a high amount of suspended particles like soil particles, microbes, algae, and other materials in water reduces the penetration of light deeper into the water. According to the World Health Organization (WHO), the turbidity of drinking water should ideally be less than 1 NTU, but turbidity of up to 5 NTU is still acceptable. A high level of turbidity can cause undesired effects such as the sticking of microorganisms to particles. In addition, many researchers have established a link between digestive system diseases and high levels of turbidity [41], [42]. The average turbidity of Kosi River water of all seasons collected from different sites is below the acceptable limit (e.i., < 1NTU). As a result, it can be stated that the water of the river is ready for direct use without treating for turbidity. A closer examination shows that there is a negative relationship between the pH and turbidity values of the river. This indicates that a higher pH value reduces the turbidity of water (e.g., [43]).

Electrical conductivity (EC) specifies the ionic forces present in the solution and the tendency of water to conduct an electrical current. Theoretically, pure water does not show EC, however, pollution induces the EC of water. In the PRM season, the electrical conductivity of river Kosi water of different sites at Ramnagar ranged between 159.7- 244.7 S/cm (Avg. = 204.15 S/cm; Std. = 27.21 S/cm) in pre-monsoon season. It was found to be 154.9- 244.7 S/cm (Avg. = 162.58 S/cm; Std. = 5.79 S/cm) during monsoon and from 153.6 to 165.47 S/cm (Avg. = 160.40 S/cm; Std. = 5.23 S/cm) in post-monsoon season. All of the values are within the acceptable range. There is a clear decrease in the electrical conductivity during monsoon which can be attributed to a high volume of water during the rainy season which decreases the concentration of ions and hence leads to a decrease in conductivity.

Total dissolved solids (TDS) as a parameter significantly affects the treatment of biological and physical water contamination[13]. TDS levels in Kosi River in PRM water ranged from 216 mg/L to 227.3 mg/L (Avg. = 221.61 mg/L; Std. = 3.63 mg/L), between 248mg/L to 257 mg/L (Avg. = 252.67 mg/L; Std. = 3.79 mg/L) during monsoon and POM water ranged from 250.67 mg/L to 252.33 mg/L (Avg. = 251.00 mg/L; Std. = 0.66 mg/L). TDS in drinking water has an allowed limit of 500 mg/L, and all of the values for water samples fall under that level. The level of TDS in stream water is influenced by the natural weathering of sedimentary rocks, which increases the presence of a large number of ions or minerals in the stream, which leads to a higher salinity level [44].

The hardness of water is caused by multivalent cations, especially Ca^{2+} and Mg^{2+} ions [45]. In PRM season TH of water collected from the river Kosi was in the range of 114.00-127.00 mg/L (Avg. = 120.12 mg/L; Std. = 5.59 mg/L) whereas during monsoon it had a range between 123.80-133.30 (Avg. = 128.24; Std. = 3.05) and POM season the TH values vary between 144.67-148 mg/L (Avg. = 146.27; Std. = 1.24). This seasonal fluctuation in TH directly depends on the variation in the concentration of Ca^{2+} and Mg^{2+}. The Ca^{2+} concentrations in PRM water of river Kosi ranged from 81.67 to 89.67 mg/L, (Avg. = 84.33 mg/L; Std. = 2.33mg/L) whereas Ca^{2+} concentrations in MON and POM water ranged from 95.28 to 98.84 mg/L (Avg. = 97.84 mg/L; Std. = 1.34 mg/L) and 106.53 to 112.6 mg/L (Avg. = 108.49 mg/L; Std. = 2.25 mg/L) respectively. Mg^{2+} was found to be present between 36.5- 40.2mg/L (Avg. = 38.00 mg/L; Std. = 1.21 mg/L) in PRM, and it ranged from 16.5- 19.8mg/L (Avg. = 18.14 mg/L; Std. = 1.20 mg/L) in Monsoon and 13.9-15mg/L (Avg. = 14.40 mg/L; Std. = 0.51 mg/L) in POM season. These values were below the WHO recommended values for calcium and magnesium limits of (100 mg/L and 30 mg/L, respectively). The TH of the river falls in the range of moderately hard water [45].

The Na level in the research area ranged from 6.93 to 7.4 mg/L (Avg. = 7.21 mg/L; Std. = 0.17 mg/L), 7.13-7.63 mg/L (Avg. = 7.33 mg/L; Std. = 0.21 mg/L) and 5.86 to 7 mg/L (Avg. = 6.40 mg/L; Std. = 0.41 mg/L) during PRM, MON and POM season, respectively.

The occurrence of Sodium (Na^+) in groundwater is predominantly attributed to silicate weathering processes and salt demineralization processes such as sodium and aluminium silicate and sodium chloride [46], [47]. On the other hand, potassium (K^+) in groundwater is mainly derived from feldspar, some micas, and clay minerals [48]. In the current study, it was found that the concentration of sodium (<8 mg/L) and potassium (<1 mg/ L) was well below the WHO limit of 200 mg/L and 10 mg/L, respectively. This indicates that the water is safe to drink and use for other domestic purposes. The low levels of sodium could be a result of low levels of NaCl, sodium and aluminium silicates in the soil of the study area [49]. The low levels of potassium could be due to the low rock mineral composition or low geochemical mobility of the sites. As a result, no contamination of sodium or potassium was detected in the water samples.

Besides, the presence and concentrations of various anions viz. Cl^-, NO_3^- and SO_4^{2-} were also analyzed for their seasonal variation in the water of river Kosi. Among these, Cl^- is produced by dissolving salts such as table salt (NaCl), sewage, and industrial waste. The Cl^- concentration in the tested samples was found in the range from 4.67 to 5.33 mg/Lin (Avg. = 4.90 mg/L; Std. = 0.29 mg/L), from 4.14 to 5.14 (Avg. = 4.55 mg/L; Std. = 0.38 mg/L) and 4 to 4.67 mg/L (Avg. = 4.29 mg/L; Std. = 0.30 mg/L) in PRM, MON and POM season.

In the PRM water, the concentrations of NO_3^- ranged from 0.51 to 0.91 mg/L, with an average of 0.73 mg/L and a standard deviation of 0.17 mg/L. On the other hand, in the MON water and POM water, the NO_3^- concentrations were in the range of 0.67 to 0.77 mg/L (average = 0.71 mg/L; standard deviation = 0.03 mg/L) and 0.59 to 0.73 mg/L (average = 0.64 mg/L; standard deviation = 0.03 mg/L), respectively. Natural NO_3^- concentrations in groundwater usually rise as a consequence of anthropogenic activities such as the discharge of domestic and septic tank effluent and agricultural activities [50]. Furthermore, water containing more than 3 mg/L of nitrite NO2- should not be used for baby feeding [51].

SO_4^{2-} concentration in PRM water was found to be 36.2 to 36.7 mg/L and 34.1 to 36.03 mg/L in the Monsoon, whereas 31.03 to 33.7 in POM season water with an average of 36.46 mg/L, 34.92 mg/L and 31.78mg/L, respectively. It is worth noting that all values fall within the acceptable limit for drinking water as per BIS (2012) guidelines. Sulphate is mostly found in water systems due to the dissolution of two types of rocks that contain sulphate; gypsum and pyrite [46]. These rocks are located beneath the springs, and their presence in the water system affects the course of the river Kosi. The river flows mainly over the Lesser Himalaya, which has relatively lower amounts of gypsum and pyrite compared to other areas [49].

IV.2 Water Quality Index (WQI)

The Water Quality Index (WQI) is an effective tool used to evaluate the quality of spring water for drinking purposes. It groups various parameters and dimensions into a single score, providing a picture of the overall water quality. The Weight Arithmetic WQI was used to determine the WQI of the Kosi River at five different sites during different seasons, and the results are shown in Fig. 2 and compiled in Table 3. During the monsoon season, the WQI is lower (18.60-29.27; Avg. 22.88), while during the pre-monsoon and post-monsoon seasons, it is higher (35.34-39.53; Avg. 37.53 and 33.41-40.72; Avg. 36.17 respectively). The WQI exhibits a significant variation in POM, indicating a gradual change in the water volume from the rainy season to the dry season that may cause a change in the physical parameters of water. Based on the values of WAWQI, the water of river Kosi falls in the good category in PRM season and POM season. However, its quality improved in the monsoon season and it falls in the Excellent category.

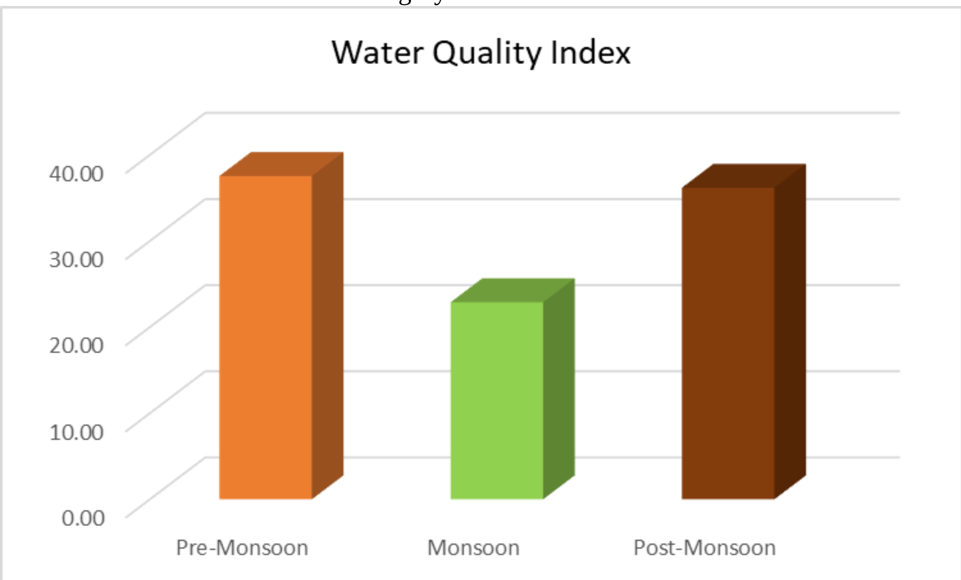

Fig. 2:
Weighted Arithmetic Water Quality Index of the study sites

This seasonal variation in the WQI can be explained based on a shift in the values of various parameters during the monsoon season. The low water quality of springs is usually due to high levels of turbidity, total hardness, magnesium, total alkalinity, nitrate, dissolved oxygen (DO), and biological oxygen demand (BOD). Scientists believe that this happens because rainwater interacts with sedimentary rock in the area, causing ions to dissolve into the water [50]. Alternatively, it could be due to improper waste disposal, cottage activities, agricultural and urban run-off, sewage, overuse of inorganic fertilizer, and poor operation and maintenance of septic systems (WHO, 2004). However, based on the WQI of the present study, the water of the Kosi River in Ramnagar can be used directly for drinking and other domestic purposes without any further treatment to reduce contamination.

Table 3: Calculation of WA WQI in the studied sites near Ramnagar, Uttarakhand during Pre- During and Post-monsoon and WQI-based rating of water quality

Site	Pre-Monsoon	Monsoon	Post-Monsoon	WQI	Water quality rating
S1	39.03	29.27	40.72	> 100	Unsuitable for drinking
S2	36.67	21.43	33.41	51–100	Acceptable
S3	35.34	18.60	34.09	26–50	Good
S4	37.10	20.98	36.82	≤ 25	Excellent
S5	39.53	24.09	35.83		
Average	**37.53**	**22.88**	**36.17**		

V. CONCLUSION

The thorough investigation of various parameters including; pH, Ca^{2+}, Mg^{2+}, Cl^-, Na^+, NO_3^-, SO_4^{2-}, and PO_4^{3-} of the water of river Kosi in the Ramnagar region helped to trace their seasonal variation and found within the permissible limit but exceed the desirable limits of the WHO (2004) standards for drinking water, that helped to measure the water quality of the river. This is not a good sign for a river which is the lifeline of many villages and towns. It was found that all the water quality parameters showed significant variation and most of these had higher values in PRM compared to POM as compared to MON season. This observation can be attributed to the effective leaching of ions due to dilution. It can be said that it is the rain that cleanses the river periodically. The calculated WQI prove that the river water falls in the excellent to good category. Keeping all the investigation and analysis, the study concludes that the water of the river Kosi is recommended for direct drinking. Also, It is the right time to think and plan for its conservation which needs accurate monitoring of WQI and implementation of measures to control the pollution so that its quality can be improved.

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