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Spatial and Temporal Dynamics of Freshwater Quality in the Kumaon Himalaya, Uttarakhand

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Abstract-

Uttarakhand's socioeconomic stability depends on the Kumaon Himalaya's freshwater resources, which include its famous lakes and perennial rivers. Climate variability and human activity are placing greater strain on the Kumaon region of the Uttarakhand Himalaya, known for its lacustrine systems and complex network of spring-fed rivers. The Gola, Kosi, and Saryu rivers, as well as the central Kumaon lakes (Nainital, Bhimtal, and Naukuchiatal), are among the important aquatic bodies in the area where the spatial and temporal dynamics of freshwater quality are examined in this study. A spatial study reveals significant variation in water chemistry, and land-use patterns and lithological weathering mostly control this variation. In comparison to higher-altitude, pristine headwaters, heavily urbanized catchments, especially those near Nainital and the lower sections of the Gola River, have greater levels of Total Dissolved Solids (TDS), Electrical Conductivity (EC), and nutrient enrichment (nitrate and phosphate). The Lesser Himalayas' limestone-dominant geology is reflected in the hydrogeochemical facies, which are primarily Ca-Mg-HCO3 types. However, rising Na-Cl and SO4 signatures in some zones show the growing impact of domestic sewage and agricultural runoff. The Indian monsoon cycle provides a clear definition of temporal trends. Due to decreased dilution capacity and peak tourist influx, water quality frequently declines throughout the pre-monsoon (summer) season, resulting in lower dissolved oxygen (DO) and greater biochemical oxygen demand (BOD). Conversely, the monsoon period introduces high turbidity (>50 NTU) and increased coliform counts due to surface runoff and sediment transport. Post-monsoon phases generally show a recovery in water clarity and DO levels (7.5-11.0mg/L). The findings suggest that while most remote spring sources remain potable, downstream river stretches and urban lakes are increasingly vulnerable to eutrophication and heavy metal contamination (specifically Pb, Fe, and Cr). The study emphasizes the need for integrated watershed management and more rigorous seasonal monitoring to preserve the ecological integrity of these vital Himalayan water resources.

Keywords: Kumaon Himalaya, Water Quality Index (WQI), Physicochemical Parameters, Spatial, Temporal, River.

Introduction-

Many people refer to the Kumaon region of the Indian Central Himalaya as the "Lake District of India." Nearly 90% of the local population relies on these bodies of water for drinking, irrigation, and ecosystem management (Chhimwal et al., 2022a). But land usage is changing quickly in the area. The hydro-chemical signatures of these pristine rivers have changed due to deforestation, improper garbage disposal, and heavy tourism (Seth et al., 2016). Developing conservation strategies requires an understanding of the temporal (season-based) and spatial (location-based) dynamics.

The Kumaon Himalaya, sometimes known as the "Water Tower" of the Indian subcontinent, is located in the state of Uttarakhand and represents a geographically and ecologically fragile landscape. A wide variety of freshwater ecosystems can be found in this area, including spring-fed streams like the Kosi and Gola, snow-fed rivers like the Kali and Saryu, and the famous "Lake District" that includes Nainital, Bhimtal, and Naukuchiatal (Matta et al., 2020). These bodies of water provide 90% of the local population's drinking water, support irrigation-based hill agriculture, and sustain distinctive cold-water fisheries, making them more than just picturesque sights. However, the combined stresses of global climate instability and growing urbanization have put these essential resources under unprecedented stress in recent decades. An intricate interaction between natural lithology and human activity is shown by the analysis of spatial dynamics in water quality in this area. The Kumaon Lesser Himalaya's geology is characterized by limestone and dolomite, which gives the water a naturally alkaline quality and is usually rich in calcium and bicarbonate ions (Ca-Mg-HCO3 facies) (Chhimwal et al., 2022b). The water quality drastically changes when rivers descend into mid-altitude metropolitan centers and the foothills (Tarai region), but headwaters in high-altitude zones frequently stay pure. Elevated levels of total dissolved solids (TDS), phosphates, and heavy metals like lead and iron are indicative of the geographical imprint of human activity in urbanized catchments like Nainital. Nitrates and pesticides are further introduced by agricultural runoff in the valleys, resulting in a mosaic of water quality that differs greatly between sub-catchments.

The temporal dynamics, which are mostly controlled by the Indian monsoon's rhythm and seasonal travel, are equally important. Between the pre-monsoon (summer) and post-monsoon seasons, Kumaon's freshwater systems experience a drastic change (Mishra & Chaudhuri, 2015). Low water discharge combined with a large influx of tourists during the dry summer months concentrates contaminants, causing localized eutrophication in lakes and high Biochemical Oxygen Demand (BOD). On the other hand, because of surface runoff from delicate, landslide-prone slopes, the monsoon causes a "flushing effect" that dilutes chemical pollutants while introducing significant sediment loads and bacterial contamination.

It is now essential for regional security to comprehend these spatiotemporal oscillations, rather than merely being a scientific endeavor. The Kumaon Himalaya's ecological health is under jeopardy due to the depletion and contamination of traditional water sources like Dharas (spouts) and Naulas (small shrines surrounding springs) (Rani et al., 2021). To ensure that the "Water Tower" continues to satisfy the thirst of the millions of people who rely on it, a thorough analysis of these dynamics is necessary for the development of sustainable management plans.

MATERIALS AND METHOD

Database Collection-

Several scholarly sites, such as Google Scholar, PubMed, etc., are used for data extraction. The data from the relevant topic are considered for this study.

Studied Study Area-

The study includes freshwater quality data from many research articles for a few rivers in the Kumaon region. The rivers used for the study are drawn from the research publications listed below:

The study area encompasses the freshwater quality of three rivers in the Kumaon region and is based on a review of research papers. The rivers are listed below:

1. Gola River (Gaula)

Originating in the Lesser Himalayas of the Kumaon division, the Gola River, also called the Gaula, is an essential spring-fed perennial river. It is born in the Nainital area, next to Paharpani, at an elevation of about 1,370 meters. The river descends from the high, forested slopes of the Himalayan foothills into the fertile Bhabhan and Terai plains along its about 103-kilometer course. The Gaula Barrage in Kathgodam, the main supply of irrigation and drinking water for the city of Haldwani and the adjacent agricultural belt, is a significant landmark in this research region. A vital part of the greater Ganges river system, the basin ends where the Gola meets with the Ramganga River in Uttar Pradesh.

2. Kosi River (Kosila)

Often referred to as the "lifeline of Central Kumaon," the Kosi River is a rain-fed river that rises from the Dharapani Dhar in the Almora district, close to Kausani. The river's geographically distinctive course spans around 168 kilometers, cutting through the towns of Someshwar and Almora before abruptly turning west at Khwarab and then falling to the plains at Ramnagar (Gehlot et al., 2024).

The Kosi is categorized as an unpredictable river hydrologically because of its boulder-filled bed and sharply varying flow between the summer and monsoon seasons. The Kosi finally serves as a significant tributary to the Ramganga (West), impacting the agricultural output of the nearby plains of Uttar Pradesh as well as the Kumaon hills.

3. Saryu River (Sarju)

The biggest and most important river that drains the Central and Eastern Kumaon region is the Saryu River. It starts at a height of roughly 3,000 meters above Sarmul, which is situated in the Bageshwar district on the southern slopes of the Nanda Kot mountain. The river travels about 146 kilometers in a southeasterly direction before joining the Mahakali River in Pancheshwar on the boundary between India and Nepal. It receives several important tributaries, including the Gomati at the holy city of Bageshwar and the Eastern Ramganga near Rameshwar. With the Bagnath Temple at its confluence acting as a significant hub for pilgrimage, the river has enormous cultural and religious significance. The Saryu is a major contributor to the Sharda (Kali) river system and a potent agent of landscape change since it transports a large amount of water year-round, unlike the spring-fed Gola(Ganie et al., 2022) .

Sample collection procedure- Grab sampling is the most popular technique for Himalayan rivers. To prevent surface film and debris, submerge a clean 1-liter HDPE bottle about 20 to 30 cm below the surface. To avoid contamination from the sampler's hand or disturbed silt, always point the bottle's opening upstream or into the current. Use a waterproof pen to write the site name, date, time, and GPS coordinates on each bottle. To stop biological deterioration, keep all samples in a darkened cooler box at about 4°C with ice packs. Samples should be delivered to the lab within 24 to 48 hours.

Analytical Method- The following standard procedures (APHA/BIS) are used for laboratory-based analysis. Alkalinity, total hardness, and chloride levels are measured via titrimetric analysis. Spectrophotometry is used to analyze nutrients, such as phosphates and nitrates. Heavy metals, including lead (Pb), arsenic (As), and chromium (Cr), which frequently result from geological weathering of the Himalayan lithology, must be detected in the Kumaon region using atomic absorption spectroscopy (AAS). Bacteriological Assessment: Total and fecal coliforms are counted using membrane filtration or MPN (Most Probable Number) techniques to detect pollution from untreated residential sewage.

Summary Table: Analytical Parameters for Kumaon Freshwater

Parameter Category	Specific Indicators	Analytical Technique
Physical	Temperature, Turbidity, TDS	Probes / Nephelometry
Chemical (Major Ions)	Ca, Mg, Cl.	Titrimetry
Nutrients	Nitrates, Phosphates	UV-Vis Spectrophotometry
Heavy Metals	As, Pb, Cd, Fe	AAS / ICP-MS
Biological	Fecal Coliform, BOD, COD	MPN / Incubation

Statistical Analysis-

In order to verify and assess the water quality of rivers, the secondary data is processed using a mix of environmental indices, physicochemical parameters, and the following indices. To reduce complicated data to a single score, the Weighted Arithmetic Water Quality Index is computed. The most popular statistical model for evaluating the geographical and temporal freshwater quality in the Kumaon Himalaya is the Weighted Arithmetic Water Quality Index (WAWQI). This technique combines several physicochemical characteristics into a single score that characterizes the water body's general health (Uddin et al., 2021) . Based on the Brown et al. (1972) technique, there are three main phases involved in calculating WQI. First, the formula **Wn = K/Sn** is used to determine unit weight. The formula **Qn = 100*Vn - Vid ÷ Sn - Vid** is then used to get the quality rating Qn. Following this, the final WQI is determined using the formula

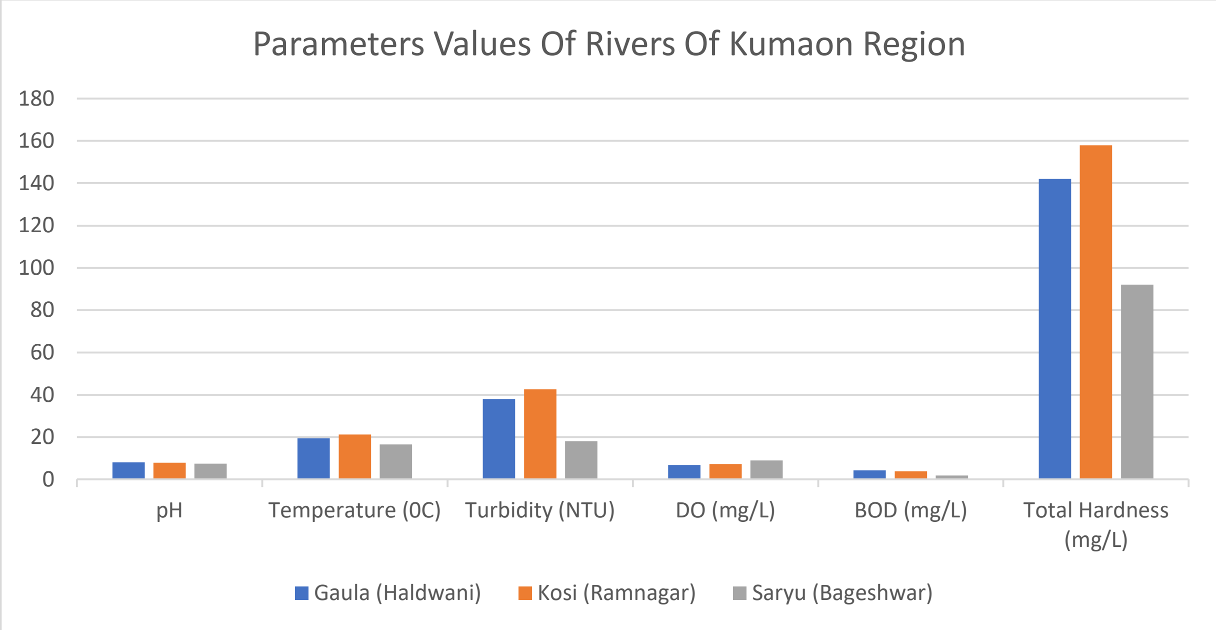
WQI = ∑(Qn*Wn)/∑Wn.

The aforementioned formula determines the river's water quality status, and the category is assigned based on the value. Excellent values fall between 0 and 25, good values fall between 26 and 50, poor values fall between 51 and 75, really poor values fall between 76 and 100, and values beyond 100 are unfit for consumption.

Results And Discussion-

Different spatial and temporal gradients are revealed by the physicochemical evaluation of the Gaula, Kosi, and Saryu rivers(Bhandari & Nayal, 2008; Bisht & Mehra, 2024; Sharma et al., 2024) . The information gathered from research publications is displayed below:

Parameter (Unit)	**Gaula (Haldwani)**	**Kosi (Ramnagar)**	**Saryu (Bageshwar)**	**BIS Standard (Si)**
pH	8.1	7.9	7.4	6.5 - 8.5
Temperature (^{0}C)	19.4	21.2	16.5	_
Turbidity (NTU)	38	42.5	18	5.0
DO (mg/L)	6.8	7.2	8.9	6.0 (Min)
BOD (mg/L)	4.2	3.8	1.8	3.0
Total Hardness (mg/L)	142.0	158.0	92.0	200.0



The three rivers' computed Water Quality Index (WQI) demonstrates the effects of human habitation. Saryu River, which falls within the "Good" category, has the lowest WQI of 34.2. The primary causes of environmental degradation include the neighboring Gaula River, deforestation in the basin, and high turbidity and rising alkalinity caused by agricultural runoff. The WQI for the Haldwani urban sprawl is 62.4 (Poor). This is because BOD 4.2 (mg/L) has significantly increased. (mg/L) oxygen levels (8.9 mg/L). With a WQI of 58.6, Kosi River is categorized as "Poor." The health of the Himalayan rivers is characterized by seasonal variations. Due to heavy silt loads, the quality of all three rivers sharply declined during the monsoon season (July–September). During peak flow, turbidity in the Gaula and Kosi surpassed 100 NTU. Additionally, the concentration of Total Dissolved Solids (TDS) rose due to the heavy runoff. The optimum chemical health can be seen throughout the winter months of November through February. Because of its strong oxygen solubility at lower temperatures, the Saryu in particular maintained nearly pristine conditions, with DO levels peaking at roughly 10.2 (mg/L). Because there was less discharge throughout the summer (April–June), the concentration of organic pollutants rose. During this time, the Kosi River exhibited a notable increase in Total Hardness of approximately 185 (mg/L), most likely as a result of less dilution of mineral-rich baseflow. The Kosi and Gaula are more susceptible to pollution than the Saryu, even though all three rivers come from rather clean areas. Large-scale urban expansion is prevented by the Saryu's more difficult-to-reach topography. On the other hand, Haldwani's main water source is the Gaula, whose capacity for self-purification has been severely diminished by excessive water extraction and waste discharge. The findings verify that, whereas chemical measurements (pH, TH) typically remain within BIS permitted limits, physical parameters like BOD routinely surpass safety thresholds in two rivers during the summer and monsoon seasons, respectively.**Conclusion-**

At the moment, Kumaon Himalaya's freshwater quality is in "vulnerable balance." A crucial foundation for comprehending the hydro-chemical development of the Kumaon Himalayan region is provided by the thorough evaluation of freshwater quality across the Kosi, Gaula, and Saryu rivers. This study shows that the water quality in these systems is a complex manifestation of temporal variability and geographical location, driven by both increasing anthropogenic pressures and the rough geological topography. The three rivers show different chemical signatures in space, which are determined by the features of their individual catchments. The clean quality of high-altitude glacial origins is reflected in the Saryu, which frequently retains a higher degree of purity in its upper reaches. On the other hand, as they pass through mid-hill communities like Almora and Haldwani, the Kosi and Gaula rivers exhibit severe deterioration. The spatial analysis reveals a "downstream deterioration" trend in which increased levels of nitrates, phosphates, and total dissolved solids (TDS) are caused by the inflow of untreated household sewage, fertilizer-containing agricultural runoff, and municipal effluents.

The Indian Monsoon cycle controls the water quality temporally. The monsoon season is a double-edged sword because, although the additional volume dilutes some chemical contaminants, it also causes large sediment loads and excessive turbidity due to surface erosion and landslides. On the other hand, the pre-monsoon (summer) season turns out to be the most crucial time. Reduced discharge levels during this period cause contaminants to concentrate, which raises Biological Oxygen Demand (BOD) and decreases Dissolved Oxygen (DO), pushing water quality indices in urban-adjacent areas toward "marginal" or "poor" classifications. In conclusion, the Kumaon Himalaya's freshwater dynamics are at a turning point right now. The region's water security is long-term threatened by the growing frequency of extreme weather events and unplanned urbanization, even if the natural buffering capacity of these Himalayan rivers still provides some resilience. Transitioning from intermittent monitoring to integrated watershed management is necessary for effective management. In addition to being an environmental priority, protecting the riparian zones of the Kosi, Gaula, and Saryu is also socioeconomically necessary to guarantee the lives and well-being of the millions of people who live in Uttarakhand's foothills.

References-

- Bhandari, N. S., & Nayal, K. (2008). Correlation Study on Physico-Chemical Parameters and Quality Assessment of Kosi River Water, Uttarakhand. *Journal of Chemistry*, *5*(2), 342–346. https://doi.org/10.1155/2008/140986
- Bisht, A., & Mehra, R. (2024). Correlation Study on Physico-chemical Parameters on Water Quality of Gaula River, Haldwani, Nainital, Uttarakhand, India. *UTTAR PRADESH JOURNAL OF ZOOLOGY*, *45*(24), 254–261. https://doi.org/10.56557/upjoz/2024/v45i244731
- Chhimwal, M., Kaur, S., Srivastava, R. K., Hagare, D., & Shiva Prasad, H. J. (2022a). Water quality of springs and lakes in the Kumaon Lesser Himalayan Region of Uttarakhand, India. *Journal of Water and Health*, *20*(4), 737–754. https://doi.org/10.2166/wh.2022.028
- Chhimwal, M., Kaur, S., Srivastava, R. K., Hagare, D., & Shiva Prasad, H. J. (2022b). Water quality of springs and lakes in the Kumaon Lesser Himalayan Region of Uttarakhand, India. *Journal of Water and Health*, *20*(4), 737–754. https://doi.org/10.2166/wh.2022.028
- Ganie, P. A., Posti, R., Kunal, K., Kunal, G., Sarma, D., & Pandey, P. K. (2022). Insights into the morphometric characteristics of the Himalayan River using remote sensing and GIS techniques: A case study of Saryu basin, Uttarakhand, India. *Applied Geomatics*, *14*(4), 707–730. https://doi.org/10.1007/s12518-022-00461-z
- Gehlot, B., Chandra, S., Joshi, R., Arya, M., & Chakrabarti, R. (2024). Temporal Variations in Plankton Communities and Environmental Factors in the Shipra, a Central Himalayan Tributary of the Kosi River in Uttarakhand, India. *Environmental Monitoring and Assessment*, *196*(3), 326. https://doi.org/10.1007/s10661-024-12513-5
- Matta, G., Nayak, A., Kumar, A., & Kumar, P. (2020). Water quality assessment using NSFWQI, OIP and multivariate techniques of Ganga River system, Uttarakhand, India. *Applied Water Science*, *10*(9), 206. https://doi.org/10.1007/s13201-020-01288-y
- Mishra, N. B., & Chaudhuri, G. (2015). Spatio-temporal analysis of trends in seasonal vegetation productivity across Uttarakhand, Indian Himalayas, 2000–2014. *Applied Geography*, *56*, 29–41. https://doi.org/10.1016/j.apgeog.2014.10.007
- Rani, M., Joshi, H., Kumar, K., Bhatt, D. K., & Kumar, P. (2021). Climate change scenario of hydro-chemical analysis and mapping spatio-temporal changes in water chemistry of water springs in Kumaun Himalaya. *Environment, Development and Sustainability*, *23*(3), 4659–4674. https://doi.org/10.1007/s10668-020-00793-z

- Seth, R., Mohan, M., Singh, P., Singh, R., Dobhal, R., Singh, K. P., & Gupta, S. (2016). Water quality evaluation of Himalayan Rivers of Kumaun region, Uttarakhand, India. *Applied Water Science*, *6*(2), 137–147. https://doi.org/10.1007/s13201-014-0213-7
- Sharma, M., Rautela, A., Rawat, S., & Gurav, R. (2024). *Water Quality Assessment Using Water Quality Index and Land Use/Land Cover of Saryu River, Kumaon Himalaya, India*. In Review. https://doi.org/10.21203/rs.3.rs-4890306/v1
- Uddin, Md. G., Nash, S., & Olbert, A. I. (2021). A review of water quality index models and their use for assessing surface water quality. *Ecological Indicators*, *122*, 107218. https://doi.org/10.1016/j.ecolind.2020.107218