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Research Article

Water quality assessment of the Song River in Dehradun, Uttarakhand

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Abstract

The Song River is among the important water bodies that traverse Dehradun in Uttarakhand. It plays a very important role in the region regarding domestic, agricultural, and ecological needs. Nevertheless, a high rate of urban development, uncontrolled tourism, and the discharge of untreated domestic and agricultural waste have created major concerns about the quality of its water. The present study has been undertaken to evaluate the prevailing status of water quality in the Song River, based on the physicochemical as well as the microbiological parameters at three strategic points located upstream (1st point), middle (2nd point), and downstream (3rd point) of the river. Sahastradhara (starting point), Sahastradhara (end point), Maldevta. The main water quality indicators that were evaluated in the course of the study include pH, turbidity, total dissolved solids (TDS), total hardness, alkalinity, nitrate, phosphate, chloride, calcium, magnesium, iron, and biological indicators such as E. coli and total coliform bacteria. The accuracy and reliability of the tests were ensured by using the standard laboratory procedures as per IS (IS 10500:2012), CPCB and WHO guidelines. The results indicate that the Maldevta site has comparatively better water quality, where most parameters are within the allowed levels. On the contrary, Sahastradhara places, especially the end-point, had more TDS, hardness, and microbial contamination, thus indicating a significant anthropogenic influence.

Keywords: TDS, E. coli, coliform bacteria, CPCB, WHO

1 Introduction

Water is a very important source, whether for aquatic species or plants, animals and humans. Rivers always help maintain ecological balance and keep the environment healthy, reflecting the impacts of human activities within their water greenhouses. Rivers are one of the primary sources of water on the Earth. As most rivers carry fresh water, they are one of the main support systems for life on Earth. However, due to numerous changes, the quality of the river has been significantly impacted, with several major factors contributing to this situation, including urbanisation and an increase in industrial activities. Knowing how a river forms is the best way to understand it. A river begins when water flows down from a higher place due to gravity. Rivers can also be defined by their type. They are either snow-fed or rain-fed. Snow-fed rivers originate from the melting of snow and glaciers, allowing them to flow throughout the year and are, therefore, classified as perennial rivers. In contrast, rainfed rivers rely on rainfall and may dry up during dry seasons. The origin of a river plays a vital role in how it forms and behaves. The formation of a river depends on three main factors: its origin, route, and mouth. If a river begins from a glacier, it is usually perennial, meaning it flows throughout the year regardless of the conditions in lower areas [1].

Water bodies have had two main functional roles throughout the historical development of human civilization. Rivers help support farming industries, industrial operations and urban land development. The activities in river-based industries and the area's resident communities suffer from indiscriminate human operations. Most rivers in Garhwal receive water from glaciers, and their chemical and biological makeup changes according to how far they are from glaciers. [1, 2] The water quality of diverse effluents reveals that human-created activities strongly damage water quality. Detrimental influence on the water quality in the downstream parts of the major rivers. Aquatic Ecological distress acting upon habitats began a few decades ago due to human-generated activities, including human activities

rooted in fast urban development and industrial production, creating major threats to all populations. Scientists use the biomonitoring technique to study the aquatic population's reactions towards environmental stress. [2]
The Song River flows through Dehradun in Uttarakhand. It is a vital water source for local communities, agriculture, and the Doon Valley's science network. The Song River originates from various small streams in the Dhanolti mountain range. The river starts from the Sahastradhara region and then moves south across the Doon Valley basins to unite with the Ganga River near Raiwala. Locally situated at 30•28' latitude and 79•8' longitude, the Song River is significant for people in Lachhiwala and the neighbouring towns Doiwala, Chiddarwala, Maldevta, and Raiwala. The wellspring of dependability produces water over a 42.5 km distance. Song River originates from the hills of Mussoorie, where it passes through varied landscapes. Finally, it joins the Sushwa River [3, 4].
This is why comprehensive studies on its water quality are limited despite its importance. Due to this, studying the Song River to completely understand its current situation and identify the factors that influence it becomes necessary. There are so many parameters which can influence the quality of water. Some important parameters include physico-chemical factors(pH, dissolved oxygen, turbidity), biological indicators (microbial diversity, macroinvertebrates), and contaminants such as heavy metals, nitrates, and organic pollutants. These factors determine the suitability for drinking, irrigation, and aquatic ecosystems of river water. Also, these factors serve as broader indicators of environmental health. Due to human activities and other factors, ecosystems of rivers are experiencing so much degradation worldwide [5].
The widespread water pollution is seen through sewage contamination in the Ganges, industrial effluents in the Yangtze, and agricultural runoff in the Mississippi. The need to address these challenges is evident in projects like the Ganga Action Plan in India. However, countries' smaller rivers, including the Song, receive much less attention in the face of their ecological and socioeconomic importance. Urban development has been occurring rapidly with the population increase in Dehra Dun. Consequently, there have been environmental concerns about the population increase [5, 6].
According to research done on the Suswa River, where the Song drains, the BOD and Coliform bacteria assessments are very high due to the discharge of wastewater into the river. However, the peculiar characteristics of the Song River's watershed make it necessary to use it in isolation. Past studies have shown measures of such seasonal variation in water quality driven by monsoon-driven runoff, tourism activities, and other similar investigations. However, Song River has yet to apply the set of national standards concerning water quality as specified by the Bureau of Indian Standards (BIS) and the Central Pollution Control Board (CPCB). The research demands that investigators collect site samples for water quality evaluation to assess temperature and pH values alongside heavy metals and microbial contamination detection through laboratory procedures. A set of sampling points extends from the Mussoorie hills to where the river meets the Suswa River [7, 8].
The process enables us to identify pollution sources sufficiently and determine natural seasonal changes, which we will use to identify areas of active contamination. Standard exposition transformation methods will apply to the areas in Doon Valley. However, additional modifications are needed to accommodate its topographical features alongside hydrological conditions.
This research yields all major impacts which combine environmental sustainability with the protection of public health. Drinking water sources experience negative water quality deterioration because of rapid habitat development, which causes ecosystem process problems and disease transmission risks during episodes of visitor growth. The collection of baseline data would serve as a foundation for future monitoring operations and produce suggested guidelines that diverse stakeholders can execute. The conservation initiative for the Song River ensures sustainability in Uttarakhand's tourism industry, together with the accomplishment of long-term conservation goals [9].
The Song River holds importance that reaches beyond its basic water system functions. This valuable watercourse serves three main functions: biodiversity preservation, agricultural water supply, and local community survival. The Song River shares the same fate as other Indian river systems because it experiences growing threats from human development, deforestation, and climate change. A multidisciplinary method, including hydrology with ecology plus socioeconomic elements, becomes essential to understand these challenges properly [9, 10].
Despite this, the Song River basin does not have an effective system for the disposal of household and industrial waste together. As Dehradun city has grown rapidly, its sewage dumping into the river has increased, with no wastewater processing. The waste disposal is done without regulation, which damages water quality and represents a major health threat to a population that depends on the river for water requirements. Heavy metals and chemical pollutants

need to be evaluated for inclusion in aquatic ecosystems, and human beings should be tested extensively because of the need to test coliform bacteria [10]. The second major source of water quality decline originates from agricultural water drainage. When farmers apply chemical fertilisers and pesticides near the river, nitrates and phosphates enter the water, causing eutrophication alongside a reduction in oxygen levels. Water quality deterioration leads to the death of aquatic organisms, which then causes death among fish populations throughout bacterial and detrital food chains.

Different seasonal nutrient loading datasets will demonstrate the remedy approaches as part of the analysis. Deforestation of natural areas disrupted river flows, which led to increased sediment amounts and water murkiness in the river waters. Water retention suffers from soil nutrient loss through erosion and water chemistry degradation because of uncontrolled deforestation. Sustainable land management and tree-planting initiatives must be implemented to resolve this problem [11]. Climate change sets up obstacles which obstruct the assessment method for water quality conditions. Environmental conditions, higher temperatures, and deteriorating weather patterns modify river hydrology and decrease water availability while deteriorating its quality. Scientists must investigate the seasonal patterns of the Song River to develop necessary water management strategies because the changing climate modifies its water levels. Strategies aimed at water preservation must receive support from residents and government agencies through partnerships with environmental organisations. Neutralising the advantages of local community-based monitoring schemes creates efficient data collection systems that boost community awareness of sustainable water practices [12]. Implementing traditional knowledge and modern methods will help create full strategies to safeguard the Song River. A review of existing water resource governance requirements is part of the research work in Uttarakhand. A complete retrospective assessment will investigate existing faults and prospects of pollution control programs, water management, and conservation initiatives. The research analyses domestic and international river rehabilitation undertakings to discover suitable restoration plans for the Song River. The wider investigative structure of this research seeks to build national educational efforts regarding river preservation across India. Available water resources need stakeholders to take preventive measures that combine evidence-based government policies with stakeholder collaboration to achieve conservation results. This research implements international approaches for freshwater ecosystem protection by developing improved environmental resistance strategies [13].

The evaluation of Song River water quality represents the last research effort in environmental studies of Uttarakhand state. The study will use information acquisition and analytical procedures to identify significant determinants influencing the river's status. Examining and analysing research results will enable river conservation policy meetings and future water resource management improvements [14]]

Rivers are essential life sources that have formed cultural development and biodiversity throughout human history. These natural water bodies suffer from degradation because urbanisation, industrialisation and population growth have happened quickly. The river flows within the Himalayan foothills region, where it maintains both ecological and cultural value and economic worth for the local area. The scientific investigation must concentrate on the Song River because human-made operations steadily damage its water purity. The goal of my thesis, "Water Quality Assessment of Song River, Dehradun", is to develop an understanding of essential watercourse challenges while working to find solutions which aim at sustaining both its conservation and effective management [15].

This research investigation has personal meaning to me since I am from Dehradun, where the Song River exists, and the subject also fulfils academic requirements. During my time in Dehradun, I got to know the Song River intimately because of its tranquil character and its essential functions for residents. When I was young, I observed the Song River carrying clear water, nourishing various species inside the valley while offering drinking water, irrigation water, and recreational possibilities. I have noticed that the water of a river changes concerningly but discreetly over time since its water has become less transparent and its water flow has decreased while urban development pushes into its riverbanks. I decided to investigate why the river changed while establishing my involvement in restoring the water body. The goal of this thesis extends beyond classroom work because it serves as my dedication to defending the natural resources that established our shared identity. Dehradun functions as Uttarakhand's capital city while experiencing accelerated growth and tourism expansion because Mussoorie and other surrounding hill destinations bring many visitors to the area. A combination of the Song River's natural beauty helps attract visitors by trimming the district's visual charm and enables recreational fishing and boating activities. A polluted water source will likely drive away visitors and damage local economic activities, making the area less appealing for economic growth. Locals in Doon Valley rely on Song River for industrial and agricultural irrigation in their water-based operations. When water becomes contaminated, it decreases agricultural harvests, damaging soil health and jeopardising food stability. The objective behind my research stems from an interest in protecting socioeconomic advantages by conducting an intensive health evaluation of the river while suggesting pollution reduction strategies [16]. This study establishes the capability to enable sustainable development in Dehradun by balancing environmental protection and economic expansion.

2 Literature review

Environmental researchers evaluate water quality to establish safety measures for water consumption, industrial processes and agricultural irrigation requirements. Providing water resources to Dehradun is vital for the Song River after its split from the Ganga River tributaries. This review of academic publications provides an extensive examination of Song River water quality studies that present important research data regarding pollution rates and environmental observations [17].

Water quality assessment requires studying multiple physical-chemical and biological characteristics. Multiple investigations have measured the different indicators found in the Song River. The physical characteristics of temperature and turbidity are fundamental determinants for analysing water quality. Turning water temperature regulates both dissolved oxygen and survival rates of aquatic life. At the same time, elevated turbidity from natural and human-made causes disrupts water clarity and biological activities. The quality of water depends heavily on the chemicals found in the water. Examinations demonstrate that Song River water acidity ranges from slightly acidic to alkaline pH levels that result from geological conditions and human-made pollution sources. Studies have established that organic pollution causes parts of the Song River to exhibit low DO concentrations, which affect aquatic organisms. The measurement of elevated BOD and COD values along urban rivers indicates domestic waste and industrial waste as pollution sources. Lead (Pb), cadmium (Cd), and arsenic (As) have been detected in specific locations due to urban runoff and industrial waste disposal activities. Total coliform, along with faecal coliform, serves as an indicator of microbial contamination throughout the Song River, especially near locations without proper sewage treatment facilities [18].

Scientific research reveals that coliform bacteria exist in the river, which creates health threats to local inhabitants. Several studies have identified urban runoff, industrial discharges, agricultural runoff and deforestation as the main pollution influences on the water quality of the Song River. Expanding urban territory and rising building operations produce water quality impairments utilizing sediment accumulation and chemical toxicity. The river becomes severely contaminated when industrial facilities release untreated or partly treated waste into it, which results in toxic substance accumulation. Agricultural areas nearby use fertilisers and pesticides, which cause nutrient buildup and eutrophication. Soil erosion in the watershed area increases due to cattle farming activities that create water quality problems for aquatic environments. Different methods have been employed to measure water quality in the Song River. Researchers conduct pollutant measurements through in-situ observation before conducting laboratory testing using spectrophotometry, atomic absorption spectrometry, and chromatography for precise contamination measurement. Several studies employ Water Quality Indices (WQI) to evaluate comprehensive water quality through multiple parameters, and they show that urban river sections demonstrate both moderate and poor water quality [19].

Sexual pollution causes biodiversity losses since researchers have observed fish loss and species diversity in macroinvertebrates. Water treatment methods should effectively remove health hazards from water sources because microbial contaminants and heavy metals exist. Proper reduction of pollutants demands installing adequate sewage treatment facilities and industrial effluent treatment systems for wastewater management. The combined effort of creating forests with soil protection programs decreases water runoff and improves water absorption in aquatic environments [20]. Justified studies show that water quality decline from various sources reduces biodiversity through diminished fish counts and lowered macroinvertebrate diversity. Water treatment methods require immediate development because microbial contaminants and heavy metals present serious health dangers to individuals. Wastewater treatment requires building effective sewage treatment plants and industrial effluent treatment units to decrease pollutant content. Efforts to plant new trees and protect soil help prevent land erosion while sustaining water levels. Integrated water resource management (IWRM) represents a recognised approach among experts to preserve the ecological state of rivers. Typically, IWRM develops a sustainable water usage framework by uniting hydrological with ecological and socioeconomic elements to support environmental protection. Research on the Song River demonstrates the necessity to implement participatory governance systems that integrate local populations with government organisations and non-profit associations into conservation programs. Studies demonstrate that sustainable development initiatives must originate from communities through their work in monitoring rivers, planting trees, and practising agriculture in secure ways to protect water quality. Recent artificial intelligence (AI) and machine learning (ML) technological developments have benefited water quality assessment. Research shows that predictive models utilise past water quality measurements to create effective pollution forecast models [21].

Research done on AI and ML implementation in the Song River ecosystem demonstrates that these technological tools help with decision-making through their capabilities to spot pollution areas while accurately forecasting contamination rates. Scientific investigations have thoroughly studied how climate change affects river water quality. The natural hydrological processes, which are affected by climate change, led to changes in water distribution and deteriorating quality due to modifications in precipitation patterns, temperature increases, and weather intensities. Studies reveal that the Song River quality declines because monsoon surface runoff increases sediment quantities and nutrient input. The decrease in water flow during dry seasons increases pollutant concentration, creating a severe hazard for aquatic organisms. Resolving water pollution problems in Indian rivers has relied heavily on policy-level solutions. Two programs, namely Namami Gange and state-level river conservation functions, work together to restore river environments through their actions on pollution reduction mechanisms and habitat preservation efforts. Environmental policy enforcement combined with pollution control technologies demonstrates the potential for substantially improving Song River water quality. The ultimate solution to proper water management requires decentralised wastewater management systems supported by rainwater collection practices and structured urban development [22].

The upcoming research agenda must concentrate on extended water quality pattern evaluation through state-of-the-art sensor systems and IoT technologies. Big data analysis connected to environmental monitoring systems provides the capability for making immediate decisions that enhance pollution control results. The solution development for water quality problems requires joint research between professionals specialising in hydrology, using ecological knowledge, handling socioeconomic needs, and applying public health expertise. Academic institutions, government agencies, and local communities must work together to establish sustainable river management practices [23].

Scientific evidence demonstrates that the Song River experiences severe water contamination problems from three main sources: urban development, industrial development, and agricultural drainage waste. Additional evaluation methods exist, but continuous observation and combined management strategies are needed to protect the river water's quality. Next-generation environmental solutions and governmental policies need research investigation to establish sustainable river water management systems practices. The Song River faces important environmental challenges regarding water contamination because multiple urban, industrial and agricultural pollutants accumulate in its waters. Scientific research repeatedly demonstrates that pollutants cause serious deterioration in water quality, damage aquatic ecosystems, and pose health risks for people. Rising urban development has caused both industrial providers and domestic sewage systems to release more waste into the river, allowing dangerous chemical substances and toxic metals to flow into the river. Drainage practices from agricultural sectors release numerous excess nutrients and pesticides, intensifying water quality deterioration. This literature analysis evaluates current studies about the main contamination origins and their effects while examining conductive assessment practices and potential restoration techniques for maintaining the ecological stability of the Song River [24].

3 Research Methodology

3.1 Study Area and Site Selection

The Song River, a major contributor to the Ganga River, was chosen for this research as it was critical to provide water for domestic and agricultural sectors and ecological purposes in the Dehradun region. Three sampling sites were selected: Maldevta (shown in Fig.1), which is an acceptable sample of a relatively natural, undisturbed area to be a control or baseline. The second is the Sahastradhara starting point(shown in Fig. 2), which depicts upstream flow before human interferences; the Third is Sahastradhara End Point(shown in Fig. 3), which is downstream flow, which is potentially affected by the local settlements or runoff. Based on the accessibility, possible sources of contamination, population density, and the vicinity of urban settlements, the selection of these sites was made [25].

3.2 Sample Collection Procedure

Standard field procedures were followed to ensure the integrity and less contamination of the collected water samples. The following procedures were adopted as follows: For a collection of water samples, polyethene bottles were sterilised and used for a physico-chemical analysis, and glass bottles with airtight caps were sterilised for microbiological testing. Preservation by refrigeration at 4° C was provided to ensure the integrity of the samples to be chemically analysed. Simultaneously, microbiological samples, which were used in the detection of Total Coliform and Escherichia coli (E. coli), were kept in ice boxes and took less than six hours before their viability would be lost. Samples were always collected during daylight hours, between 8:00 AM and 12:00 PM, to prevent temporal variation. The bottles were rinsed three times with the river water to be sampled prior to final sampling. The latter sampling began about four hours after the release of the detritus traps. All the samples were properly labelled with date, time and the exact spot they were collected [26].

The parameters of the Indian Standards **IS 10500:2012** were used for the water quality assessment. All these parameters were categorised into *physical*, *chemical*, and *biological* parameters.In Physical parameters, pH, turbidity, total dissolved solids (TDS), colour, and odour. In Chemical parameters, Total hardness (expressed as $CaCO_3$), alkalinity, calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), nitrate ($NO_3{}^-$), sulphate ($SO_4{}^{2-}$), and iron (Fe). IN Biological parameters, Total Coliform an *E. coli*.

Standard laboratory parameter of each was examined according to the BIS (Bureau of Indian Standards) standard. A digital pH meter was used to measure the PH, which was calibrated before each test. Turbidity was determined using a Nephelometric Turbidity Unit (NTU) meter, while TDS was determined by the use of a TDS meter or by a gravimetric method in which the sample was evaporated and weighed. It was found that instead of determining the total hardness inside the water by titrating it with EDTA and the indicator Eriochrome Black T., A complexometric titration of the sample was performed with EDTA to obtain calcium and magnesium concentrations, where calcium was measured and magnesium was calculated as calcium subtracted from total hardness [27].

Argentometric titration with silver nitrate was used to determine the chloride content. After appropriate preparation, the levels of nitrate and sulfate were determined by UV spectrophotometric methods. Phenanthroline was used to analyse iron concentration, either using the phenanthroline method or atomic absorption spectrophotometry, depending on the sensitivity required.

The microbiological tests for E. coli and Total Coliform were done using the multiple tube fermentation technique, conducted after the Most Probable Number (MPN) approach, which is based on statistical probability of estimating the concentration of microorganisms.

3.3 Quality Assurance and Quality Control (QA/QC

Several quality assurance and quality control (QA/QC) items were strictly followed to ensure the accuracy, reliability and validity of the analytical results throughout the study. All instruments were carefully calibrated before any analysis of the sample. At regular intervals, duplicate and blank samples were analysed to check for procedural errors or contamination. During testing, only high-purity reagents of mass spectrometry grade were used, and distilled water alone was used for all preparations to avoid any introduction of impurities. Moreover, the analyses acquired data that were cross-checked against existing validated and well-referenced datasets for accuracy and consistency [28].

3.4 Data Interpretation and Comparison

The values corresponding to each parameter were compared with Indian Drinking Water Standards (IS 10500:2012) to assess the suitability for drinking and drinking water. Data was put into tabular form, and trends were analysed. Inter-comparisons between sampling locations were used to assess the variation of pollution load. Flags were raised over exceedances above the acceptable or permissible levels. Specific attention was paid to microbial contamination, hardness, TDS, and alkalinity, which highly impact drinking water quality.

Figure 1: Image of the Song River located in Maldevta, Dehradun, Uttarakhand

Figure 2: Image of the Song River located in Sahastradhara (Starting point), Dehradun, Uttarakhand

Figure 3: Image of the Song River located in Sahastradhara (endpoint), Dehradun, Uttarakhand

4 Results and Discussion

4.1 pH and General Chemistry

Overall, the three locations' pH values range from normal to alkaline. However, the Maldevta-1 sample records a higher value (8.78), which lies above the upper limit and may suggest an excessive presence of alkaline substances. While not life-threatening, lengthy exposure to highly alkaline water can compromise taste and result in scaling in water systems.

Discussion: The high pH level recorded at Maldevta-1 depicts that the water is in contact with alkaline-rich rocks such as limestone and dolomite, thus releasing bicarbonates and carbonates into the water. Organic activity and less anthropogenic pollution can also decrease acidic compounds and make the water more alkaline. This is a normal process of groundwater or spring-fed systems that go through a carbonate geology.

Table 1: Summary of Methods and Methodology

Parameter	**Description**	**Remarks**
Study Area	Song River, Dehradun (Uttarakhand)	Three sampling sites were selected
Sampling Sites	1. Sahastradhara (Start) 2. Sahastradhara (End) 3. Maldevta	Chosen based on human activity and natural conditions
Sampling Time	Daytime (8 AM to 12 PM)	To ensure uniformity
Sample Collection	Sterilised bottles (Polyethene for chemical; Glass for biological)	Labelled with date, time, location
Preservation	Refrigerated at 4°C for chemical; Icebox for biological	Tested within 6 hours
Parameters Analysed	pH, TDS, Turbidity, Hardness, Alkalinity, Ca, Mg, Cl^-, NO_3^-, SO_4^{2-}, Fe, Coliform, *E. coli*	Using standard procedures
Standards Followed	IS 10500:2012, BIS, WHO, CPCB guidelines	Ensures data reliability
QA/QC Measures	Instrument calibration, duplicate analysis, and blank samples	Validated by known standards

4.2 TDS and Hardness record values

The TDS levels at Sahastradhara's starting and End Points are much above the acceptable limit of 500mg/l, approaching or exceeding the permitted wharfage of 2000 mg/l. Maldevta-1, in contrast, reveals a significantly lesser TDS content (314 mg/l), which means that this region has a better quality of water. The same is true of the total hardness in Sahastradhara locations (794–880 mg/l, far exceeding both acceptable (200 mg/l) and permissible limits (600 mg/l). High hardness levels can cause pipes and appliances to scale, decrease soap efficacy, and produce gastrointestinal distress. Maldevta-1 also displays better quality on the hardness level with 238 mg/l, slightly above permitted but within the limit. The

- **Sahastradhara (High TDS):** High TDS values indicate intense rock-water interactions, which involve minerals such as calcium, magnesium and sodium, which dissolve in water. Apart from this, urban runoff, activities by man, and geothermal mineral springs in the area could supply additional salts and salts, thus increasing TDS.
- **Maldevta-1 (Low TDS):** Regarding the low TDS level, there is a suggestion of less mineral leaching or less exposure to mineral-rich soils, which means the water is relatively clean, that might be sourced from the natural recharge zones with minimal urban or geological interferences.
- **Sahastradhara (Very High Hardness)**: The very high hardness levels are caused by excessive calcium and magnesium ions, which abound in water and seep through the limestone formations, dolomite or gypsum formations. The mineral content appears to be quite important in the area's geology.
- **Maldevta-1 (Moderate Hardness):** Slight increases refer to contact with hard rock strata, but not as intensely as with Sahastradhara. This makes the water convenient to use domestically with reduced scaling possibilities.

4.3 Turbidity and Colour

Turbidity values are marginally outside the acceptable 1 NTU limit at Sahastradhara locations but never rise above the allowed 5 NTU limit. The water is visually perceptible as clear in all samples, with Hazen values being less than

1, indicating that the aesthetic quality is unaffected.
Discussion:

- textbfSahastradhara (Slightly Elevated Turbidity): The turbidity could result from surface runoffs, slight soil erosions, or suspended particles from the presence of human beings, bathing, or activities in water bodies. However, the values are kept within the limits, and Hazen ¡1 confirms the water is visually clear.

4.4 All Samples (Low Colour)

The low colour levels indicate little organic decomposition or lack of industrial waste, and the water most probably comes from clean sources, and neither chemicals are discharged, keeping aesthetic quality.

4.5 In the case of major ions (Calcium, Magnesium, Sulphate, Chloride)

There is a conspicuously high concentration of calcium and magnesium at the Sahastradhara points. Magnesium levels (114.21–136.08 mg/l) are above the acceptable level of 100 mg/l. Hence, there is a laxative danger of drinking over protracted periods. The Maldevta-1 source is characterised by comparatively depressed but alarming amounts of these minerals. Sulphate and chloride contents throughout all samples are far below harmful levels; hence little contamination of samples with industrial or agricultural runoff.
Discussion:

- **Sahastradhara (High Ca & Mg):** Such high concentrations are typical for the water that percolates through carbonate-rich rocks, which inherently leach calcium and magnesium ions. Minor contributions from the hot springs or underground mineral deposits might also contribute to the area, explaining the elevated levels.
- **Maldevta-1 (Moderate Ca & Mg):** Renders the water to have some contact with mineral origins but in lower geological concentrations.
- **Sulphate & Chloride (Low throughout):** The lack of a significant amount of these ions indicates no major industrial workings, use of fertilisers or sewage seepage into the water sources. This means low anthropogenic pollution so that the water is chemically safe

4.6 Biological Contaminants

The presence of Total Coliforms and E. Coli in the Sahastradhara starting and End Point samples is an observation of great significance. This means fecal contamination and is a major public health risk; the water probably contains agents that can lead to diseases such as diarrhoea, Typhoid, or cholera. Maldevta-1, which does not contain such bacteria, is safe to eat in microbiological terms.

Discussion:

- **Sahastradhara (Presence of Pathogens):** The presence of coliforms and E. coli is an indication of fecal contamination, most probably because of human activities around the water sources, like open defecation, wrong disposal of sewage or bathing in streams, etc. Sahastradhara is a tourist spot and is open to microbial contamination.
- **Maldevta-1 (No Pathogens):** The lack of such contaminants means better source protection, little human intervention, or natural filtration via soil that filters out biological agents before the water reaches the surface.

4.7 Other Parameters

Mean iron levels in all three samples are below the acceptable limit (1.0 mg/l); thus, there is no metallic taste or staining risk. Odour was found to be pleasant in all samples; therefore, the aesthetic acceptability of the water was retained.
Discussion: Iron (Below Limit in All Samples): Indicates that the water does not pass through iron-rich soils or rocks, and there is no industrial discharge adding iron. This helps avoid staining, metallic taste, or health issues.

4.8 Odour (Pleasant in All Samples)

Suggests low organic pollution, absence of algal blooms, industrial waste, or sewage—all of which could cause foul smells. The sources are likely naturally flowing and well-oxygenated, maintaining good olfactory quality. The three

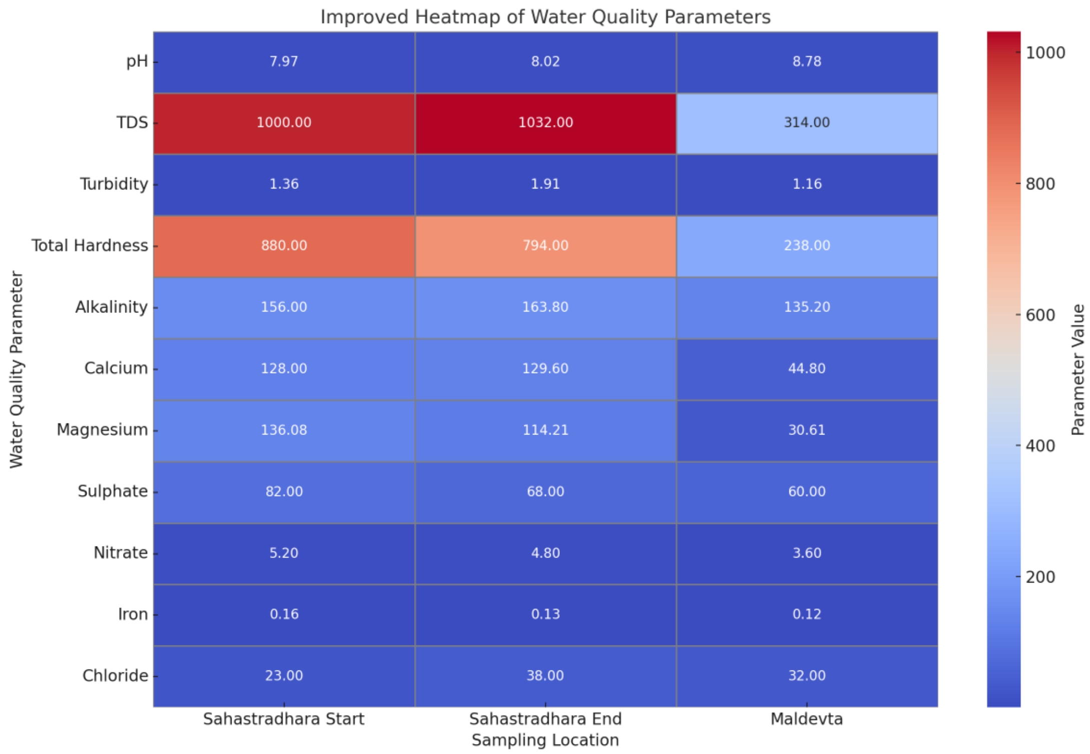

Figure 4: The intensity of colour represents levels of pollution in three Song River sites using a heatmap

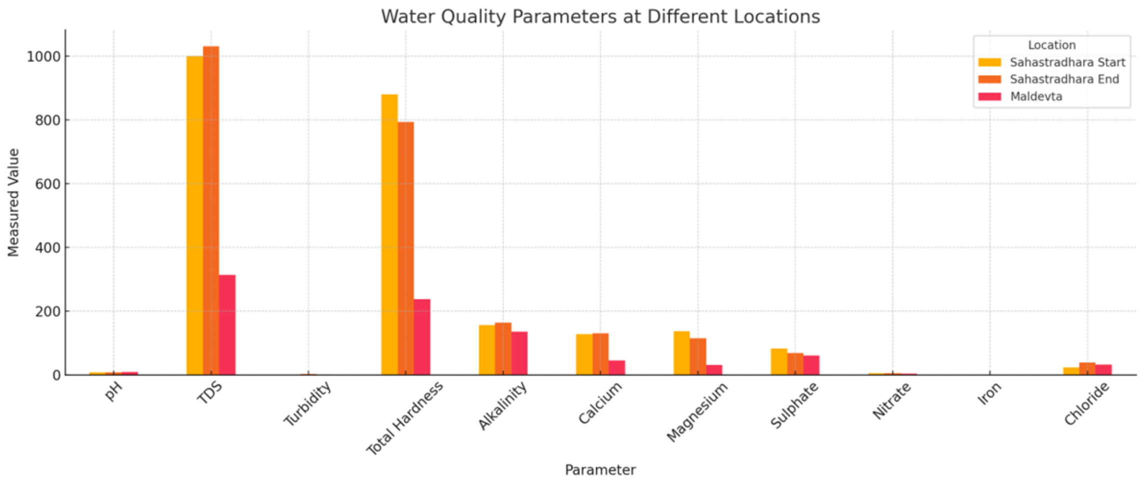

Figure 5: Comparison of water quality parameters in all sampling sites.

locations along the Song River where the water quality was analysed are Sahastradhara Start, Sahastradhara End and Maldevta, and the heatmap shows the visualisation of water quality at these locations. Rows indicate various water quality parameters such as Total Dissolved Solids (TDS), pH, hardness and the concentration levels are shown in colours. Values coloured blue indicate low values that indicate safe conditions of water; moderate values coloured white, which suggest that the values are still within acceptable limits; values colored red, which indicate that the values are close to the hazardous condition. The blue colour of the heat map shows that Maldevta mostly has blue colours, which indicate that Maldevta has good water quality and low pollution. Whereas, Sahastradhara Start and End have many red zones, by way of parameters like TDS, hardness, magnesium, calcium, etc., which point to probable contamination. The advantages of this tool are that it effectively identifies the differences in water quality among the sites, thus making it easy to figure out the areas that need intervention.

A bar graph has been illustrated for comparative analysis of water quality parameters between the different sampling sites, such as Sahastradhara Start, Sahastradhara End and Maldevta. All of them are highlighting the variation in the concentration of each parameter for these locations. It is to be noted that the TDS, hardness levels of both Sahastradhara Start and End show higher values, considering the threats of providing water of bad quality. On the contrary, Maldevta shows comparatively low values for most of the parameters, which indicate better water quality. This kind of graph facilitates the visual representation of quantitative differences in water quality elements among the different sites on the basis of comparison.

5 Conclusion

Water quality evaluation along the Song River in Dehradun shows substantial variation between sampling sites. The Maldevta-1 site presents better water quality, acceptable levels of TDS, hardness and no contamination by microorganisms. The Sahastradhara Starting and End Point samples show high values of TDS and hardness, indicating pollution by natural and human-induced sources. The existence of E. coli and Total Coliforms in these areas is cause for great concern, implicating sewage filtration. Although pH, turbidity and sulfate are acceptable, the documented quality at SBS points is substandard drinking water quality. The results demonstrate the need for better waste management and pollution control adjustments in downstream areas. In order to protect the river, continuous monitoring is necessary, and members of the public also need to be aware of the prevailing situation. Sustainable practices should be put in place. Necessary intervention is required to promote water safety for communities around and maintain ecological integrity in the Song River.

References

[1] A. P. H. Association, *Standard methods for the examination of water and wastewater*. American public health association., 1926, vol. 6.

[2] H. B. Amor, A. Elaoud, and M. Hozayn, “Does magnetic field change water ph?” *Asian Research Journal of Agriculture*, vol. 8, no. 1, pp. 1–7, 2018.

[3] A. A. Anju Agrawal, R. Pandey, and B. S. Bechan Sharma, “Water pollution with special reference to pesticide contamination in india.” 2010.

[4] K. Bahukandi and N. J. Ahuja, “Building block methodology assisted knowledge-based system for environmental-flow assessment of suswa river of dehradun dist., india: A reminiscent framework,” *International Research Journal of Environment Sciences*, vol. 2, no. 12, pp. 74–80, 2013.

[5] R. Bhutiani, D. Khanna, D. B. Kulkarni, and M. Ruhela, “Assessment of ganga river ecosystem at haridwar, uttarakhand, india with reference to water quality indices,” *Applied Water Science*, vol. 6, no. 2, pp. 107–113, 2016.

[6] S. Bartarya and D. K. Bahukhandi, “Impact assessment of urbanization and industrialization on surface and groundwater quality,” *Global Journal of Engineering Design & Technology*, vol. 1, no. 1, pp. 11–22, 2012.

[7] J. Dey, S. Sakhre, V. Gupta, R. Vijay, S. Pathak, R. Biniwale, and R. Kumar, “Geospatial assessment of tourism impact on land environment of dehradun, uttarakhand, india,” *Environmental monitoring and assessment*, vol. 190, no. 4, p. 181, 2018.

[8] R. C. Estoque and Y. Murayama, “Landscape pattern and ecosystem service value changes: Implications for environmental sustainability planning for the rapidly urbanizing summer capital of the philippines,” *Landscape and urban planning*, vol. 116, pp. 60–72, 2013.

[9] G. Fayomi, S. Mini, O. Fayomi, T. Owodolu, A. Ayoola, and O. Wusu, “A mini review on the impact of sewage disposal on environment and ecosystem,” in *IOP Conference Series: Earth and Environmental Science*, vol. 331, no. 1. IOP Publishing, 2019, p. 012040.

[10] M. V. Kishore and A. Garg, “Issues and solutions of drainage system for dehradun city,” *Indian Journal of Applied Research. The Global Journals*, vol. 4, no. 4, pp. 152–3, 2011.

[11] A. Kansal, N. A. Siddiqui, and A. Gautam, “Assessment of heavy metals and their interrelationships with some physicochemical parameters in eco-efficient rivers of himalayan region,” *Environmental monitoring and assessment*, vol. 185, no. 3, pp. 2553–2563, 2013.

[12] D. Karunanidhi, P. Aravinthasamy, T. Subramani, and R. Setia, “Effects of covid-19 pandemic lockdown on microbial and metals contaminations in a part of thirumanimuthar river, south india: A comparative health hazard perspective,” *Journal of Hazardous Materials*, vol. 416, p. 125909, 2021.

[13] D. Khanna, R. Bhutiani, G. Matta, and F. Ishaq, “Physico-chemical and microbiological status of river asan in dehradun uttarakhand,” *Environment Conservation Journal*, vol. 13, no. 1&2, pp. 145–150, 2012.

[14] D. Khanna, V. Singh, R. Bhutiani, K. S. Chandra, G. Matta, and D. Kumar, “A study of biotic and abiotic factors of song river at dehradun, uttarakhand,” *Environment Conservation Journal*, vol. 8, no. 3, pp. 117–126, 2007.

[15] N. Khatri and S. Tyagi, “Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas,” *Frontiers in life science*, vol. 8, no. 1, pp. 23–39, 2015.

[16] H. Kulshrestha and S. Sharma, “Impact of mass bathing during ardhkumbh on water quality status of river ganga,” *Journal of Environmental Biology*, vol. 37, no. 2, pp. 437–440, 2006.

[17] A. Nandan, B. P. Yadav, S. Baksi, and D. Bose, “Recent scenario of solid waste management in india,” *World Scientific News*, no. 66, pp. 56–74, 2017.

[18] A. Nandan, N. Siddiqui, C. Singh, A. Aeri, W. Gwenzi, J. O. Ighalo, P. de Carvalho Nagliate, L. Meili, P. Singh, N. Chaukura *et al.*, “Covid-19 pandemic in uttarakhand, india: Environmental recovery or degradation?” *Journal of environmental chemical engineering*, vol. 9, no. 6, p. 106595, 2021.

[19] C. Nilsson and B. M. Renöfält, “Linking flow regime and water quality in rivers: a challenge to adaptive catchment management,” *Ecology and Society*, vol. 13, no. 2, 2008.

[20] R. V. Niyobuhungiro and C. J. Schenck, “The dynamics of indiscriminate/illegal dumping of waste in fisantekraal, cape town, south africa,” *Journal of Environmental Management*, vol. 293, p. 112954, 2021.

[21] S. Padgelwar, A. Nandan, and A. K. Mishra, “Plastic waste management and current scenario in india: a review,” *International Journal of Environmental Analytical Chemistry*, vol. 101, no. 13, pp. 1894–1906, 2021.

[22] S. S. Pathak and P. Mishra, “A review of the ganga river water pollution along major urban centres in the state of uttar pradesh, india,” *Int. Res. J. Eng. Technol*, vol. 7, no. 3, pp. 1202–1210, 2020.

[23] V. I. Pierini, N. Mazzeo, M. Cazenave, and M. Semmartin, “Waste generation and pro-environmental behaviors at household level: A citizen science study in buenos aires (argentina),” *Resources, Conservation and Recycling*, vol. 170, p. 105560, 2021.

[24] D. Rana and N. Joshi, “Assessment of human intervention on ecology of river—a case study,” in *International conference on advances and innovations in recycling engineering*. Springer, 2021, pp. 51–70.

[25] D. K. Tripathi, G. Pandey, and C. Jain, “Physicochemical analysis of selected springs water samples of dehradun city, uttarakhand, india,” *Int J for Innov Res Sci Tech*, vol. 2, no. 5, pp. 99–103, 2015.

[26] R. Trivedy and P. Goel, *Chemical and biological methods for water pollution studies*. Environmental publications, 1984.

[27] S. Vijayaraman, P. Mondal, A. Nandan, and N. A. Siddiqui, “Presence of microplastic in water bodies and its impact on human health,” in *Advances in Air Pollution Profiling and Control: Select Proceedings of HSFEA 2018*. Springer, 2020, pp. 57–65.

[28] M. T. Wan, J.-n. Kuo, and J. Pasternak, “Residues of endosulfan and other selected organochlorine pesticides in farm areas of the lower fraser valley, british columbia, canada,” *Journal of Environmental Quality*, vol. 34, no. 4, pp. 1186–1193, 2005.