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Physico-Chemical Analysis of Asan River Water in the Monsoon Season in Uttrakhand, India.

Mitasha Kaushik[1], and Manish Sharma[2] †
[1] School of Science and Technology, Jigyasa University Dehradun, Uttarakhand, India.
[2] School of Science and Technology, Jigyasa University Dehradun, Uttarakhand, India.
†Corresponding author: **msresearchmani@gmail.com.**

Manish Sharma: https://orcid.org/0000-0001-9253-5923; Mitasha Kaushik: https://orcid.org/0009-0000-3067-184X

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ABSTRACT

This study focuses the persistent need for safe drinking water by conducting a seasonal assessment of the Asan River, a tributary of the Yamuna River in Dehradun, Uttarakhand, India. During the monsoon season (July-August) of 2024, five number of water samples were collected from various locations along a 40 km stretch of the Asan River. The research evaluated thirty physico-chemical and biological parameters, including temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), turbidity, and ion concentrations, along with bacterial counts. The study shows the negative correlation coefficient of -0.811 between temperature and biochemical oxygen demand (BOD), suggesting that as temperature increases, BOD tends to decrease. The findings demonstrate the relations between pH and major water quality indicators. The findings emphasize the urgent need for continuous monitoring and effective management of river ecosystems to ensure water quality and public health protection amidst increasing pollution challenges.

INTRODUCTION

Water is a vital resource for sustaining life, yet its availability and quality are increasingly compromised by pollution, particularly in India. The improper disposal of hazardous wastes into rivers, driven by rapid urbanization and industrialization, has significantly deteriorated water quality. Migration and industrial development have detrimental effects on the environment, particularly on water, air, and soil (Huff & Angeles, 2011; Cassidy et al., 2014). Since air and water are essential for all life on Earth, their contamination poses a significant threat to ecosystems and human well-being. The monitoring and assessment of air and water quality have become increasingly critical in recent years, with their deterioration worsening steadily each year (Varol et al. 2012). Water is fundamental to life and ecosystems, yet its quality is increasingly threatened by pollution. Although Earth holds 70% of its surface water, much of it is contaminated by harmful substances, posing severe risks to human and ecological health. Regular monitoring of drinking water quality is essential, as the consumption of contaminated water leads to widespread waterborne diseases and significantly influences public health. Natural water systems accumulate impurities from processes like rock weathering, soil leaching, atmospheric deposition, and anthropogenic activities, including industrialization and urbanization. Unregulated industrial growth and rapid urbanization, particularly along riverbanks, exacerbate pollution levels, altering the physical, chemical, and biological properties of water. These changes threaten aquatic ecosystems, disrupt hydro-biological cycles, and degrade life-sustaining resources. Historical evidence highlights rivers as lifelines of civilizations, yet modern pollution—driven by population growth, unplanned development, and industrial waste—jeopardizes their viability. Immediate action is imperative to ensure sustainable water management and protect ecosystems and human health. Some of the recent studies shows that numerous exposed source of surface water structure invite the contaminants from human activities and natural changes like climate change (Akhtar et al. 2021). The Yamuna River is one well-known example of how urban rivers are severely impacted by pollution. A comprehensive grasp of the ways in which urbanization affects water quality is necessary to successfully address this issue (Lokhande et al., 2019). Most of the freshwater required for drinking and cultivation comes from rivers. It is India's longest river and the second-largest tributary of the Ganga, with a total catchment area of 345,848 km². It reaches a height of 6387 m1 in Uttrakhand's Yamunotri Glacier. Before reaching the Ganga at Triveni Sangam in Prayagraj, Uttar Pradesh, it travels 1376 kilometers through the four major Indian states of Uttarakhand, Haryana, Delhi, and Uttar Pradesh (Lokhande et al. 2019). Storm water runoff, sewage discharge, and agricultural waste contribute significantly to the pollution of aquatic ecosystems, leading to eutrophication—the nutrient-driven aging and degradation of water bodies caused by the accumulation of sediments, silt, and organic matter (A. Agrawal, 1980). However, water quality is a multifaceted concept that extends beyond biological properties to include physical, chemical, and aesthetic characteristics (Bui et al., 2019).

Currently, 36% of India is urban and 65% of its rural population rely on contaminated drinking water (WHO, 2004). Pollution from untreated industrial waste, improperly managed household trash, and agricultural runoff remains a primary cause of surface water contamination (Jamal et al. 2021). These factors pose serious threats to water resources and sustainable development, underscoring the urgent need for effective water management and pollution control strategies. Water quality testing is essential before using it for drinking, domestic, agricultural, or industrial purposes. The selection of testing parameters depends on the intended use and the required quality. Water contains various impurities—floating, dissolved, suspended, microbiological, and bacterial—which necessitate comprehensive testing. Physical parameters such as temperature, color, odor, pH, turbidity, and total dissolved solids (TDS) are assessed alongside chemical parameters like biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), alkalinity, hardness, heavy metal content, and pesticide residues. Drinking water must meet stringent standards, including the required mineral levels, to ensure safety and quality. Regular monitoring of physico-chemical parameters is crucial to ensure water safety and sustainability (Patil et al. 2012).

1.1 Water quality parameters and their significance

Color, Temperature and Odor: Natural acids like fulvic and humic acids, metallic ions, and organic matter such as planktons contribute to water color, which limits light penetration, affecting aquatic life and causing eutrophication. Whereas, the Water temperature influence chemical reaction in aquatic life, growth, reproduction and disease resistance. Seasonal variations in water temperature affect biogeochemical processes in aquatic ecosystems. Extreme changes can be fatal to fish. The Organic decay, phytoplankton, and gases like ammonia and hydrogen sulfide are key contributors to water odor. Odor determination relies on organoleptic tests (Patil et al. 2012).

pH determines its corrosive nature, with low pH indicating high acidity and high pH reducing photosynthesis and increasing bicarbonates, while balanced pH supports biochemical processes in organisms. Turbidity, caused by particles like silt and clay, shields pathogens and impairs chlorine effectiveness, increasing the risk of waterborne diseases. Alkalinity, which measures the water's ability to neutralize acids, is influenced by bicarbonates and carbonates; low alkalinity leads to rapid pH shifts, and high alkalinity can cause scaling and taste issues. Lastly, total hardness, caused by calcium and magnesium, affects water usability—hard water can lead to kidney stones and heart problems, while soft water reduces corrosion.

Calcium & Magnesium are essential for bones and muscles, but excess levels can cause health issues. Ammonia indicates fecal contamination and high levels are toxic. Iron is necessary for oxygen transport but excess iron can cause taste, odor, and staining problems. Oxygen-related parameters such as Dissolved Oxygen (DO) are vital for aquatic life, with low levels indicating contamination, while BOD and COD measure oxygen used by microbes and required for chemical oxidation, respectively, with high COD levels harming aquatic ecosystems. Chemical contaminants like Nitrates and Fluorides reduce blood oxygen levels and cause skeletal issues in excess, while Chloride and Sulfates affect taste, health, and cause skin irritation. Lead and Mercury are toxic metals that cause chronic poisoning, kidney damage, and neurological issues. TDS improves water conductivity but can harm individuals with kidney issues, and TSS indicates particulate matter that reduces clarity and oxygen levels. Finally, bacteriological quality is critical, as high bacteria counts, including E. coli and coliforms, cause diseases like cholera, typhoid, and dysentery, requiring proper treatment. Jordaan et al. (2019) conducted a study on the Wonderfonteinspruit River, examining the impact of anthropogenic contaminants on bacterial communities, and reported similar findings.

Premlata (2009) studied the chemical characteristics of Pichola Lake water, examining parameters such as air and water temperature, pH, free CO2, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), conductivity, total dissolved solids (TDS), hardness, total alkalinity, chloride, nitrate, phosphate, and sulphate. The results showed that conductivity, COD, and sulphate levels exceeded standard limits. Additionally, the correlation coefficient (R) between various physico-chemical parameters was calculated. Significant reductions in color, COD, lignin content, and total phenols were observed after bio treatment at both pH levels, with greater removal efficiency at pH 5.5. These pollutants, primarily from industrial effluents, pose risks to aquatic life. Saravana et al. (2008) examined groundwater quality in the Ambattur industrial area of Chennai, analyzing parameters such as pH, total alkalinity, total hardness, turbidity, chloride, sulphate, fluoride, total dissolved solids (TDS), and conductivity. The study found slight instability in the physicochemical parameters, and comparisons with WHO and ICMR standards revealed high contamination levels, presenting health risks for human use. Manjare et al. (2010) studied the physicochemical parameters of Tamadalge Water Tank in Kolhapur, Maharashtra, over one year. Parameters like water temperature, transparency, turbidity, TDS, pH, DO, free CO2, total hardness, chlorides, alkalinity, phosphates, and nitrates were within permissible limits, indicating that the tank is non-polluted and suitable for domestic and irrigation use.

The present study demonstrate the study of physico-chemical and microbiological parameters of Asan River water during the monsoon period at five sites. The various parameters studied includes temperature, color, odor, pH, DO, BOD, COD, TSS, TDS, turbidity, total hardness, calcium, magnesium, lead, mercury, sodium, potassium, alkalinity, chloride, sulphate, nitrate, fluoride, ammonia, surfactants, iron, phenols, total bacteria count. All of the parameters were statistically analyzed using the software SPSS and compared with the recent studies.

1. MATERIALS AND METHODS

2.1 Site Description and Research Methodology

This study includes key sampling locations along the Asan River, each identified by its precise geographical coordinates. The Asan River originates from the southern side of the spring-fed headwaters in the Mussoorie range, near the PKL Bridge in Gajiyawala (Birpur) at 30°36'86875" N, 78°04'13942" E. The river is situated at an altitude of 646.8 meters (2,121 feet) above sea level (Figure 1).

The Herbertpur Asan river i.e. S-01 (30.45^0 N & 77.73^0 E) serving as an important hydrological site. Moving downstream, Rampur i.e. S-02 (30.35^0 N & 77.82^0 E) followed by Dhoolkot i.e. S-03 (30.33^0 N, & 77.88^0 E). Further along, Premnagar i.e. S-04 (30.34^0 N, 77.95^0 E), contributing to the dynamic water system of the river. Finally, Gajiyawala-Birpur S-05 (30.36^0 N, 78.04^0 E) represents the origin of the Asan River, a significant tributary of the Yamuna River.

Water Sample along the Asan River – Sample 1 (S-01) at Herbertpur Asan Bridge, Sample 2 (S-02) at Rampur, Sample 3 (S-03) at Dhoolkot, Sample 4 (S-04) at Premnagar, and Sample 5 (S-05) at Gajiyawala (Birpur) were collected during monsoon season (July-August) of 2024 from various locations along a 40 km stretch of the river (Figure 2). The Asan River water quality physicochemical parameters analyzed using standardized methods as per APHA (American Public Health Association) guidelines and (Indian Standards) specifications.

Table 1 demonstrate the series of laboratory tests conducted with used equipment and Reference. The spectroscopic method was performed following APHA-2120C, while temperature was measured using a thermometer (APHA-2012). Odor was assessed with an olfactometer (APHA-2150B), and pH was determined using a pH meter (APHA-4500 B). Turbidity (NTU) was measured using a nephelometric meter (IS: 3025 P-10:1984), and alkalinity was analyzed by titration (APHA-2320B).Total hardness, calcium, and magnesium concentrations were determined using the EDTA titrimetric method (APHA-2340C, APHA-3500). Ammonia levels were measured with an ammonia distillation flask (IS: 3025 P-34:1998). Biochemical oxygen demand (BOD) was assessed using the 5-day BOD test method (APHA-5210B), while total dissolved solids (TDS) were determined by drying at 180°C (APHA-2540C), and total suspended solids (TSS) were analyzed through drying at 103–105°C (APHA-2540D). Chlorides were quantified using titration (IS: 3025 P-32:1988), sulfates were analyzed by the turbid metric method (IS: 3025 P-24:2022), and nitrates (NO_3^-) were measured using a spectrophotometer (IS: 3025 P-34:1988). Fluoride levels were assessed using APHA-4500 F.D. (24th edition), while iron, lead, and mercury concentrations were determined using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (IS: 3025 P-65:2022). Hydrogen sulfide (H_2S) was analyzed using the test tube method (IS: 3025 P-29:1986). Sodium (Na^+) and potassium (K^+) concentrations were measured using a flame photometer (IS: 3025 P-45:1993). Dissolved oxygen (DO) was determined using Winkler's iodometric method (APHA-4500-O B), while chemical oxygen demand (COD) was analyzed using the open reflux method (APHA-5220B). Electrical conductivity was measured using an electrical conductivity meter (APHA-2510B). For microbiological analysis, total bacterial count, E. coli, and coliform bacteria were assessed using a filtration assembly and incubator, following IS 5402 (P-1):2021 and IS 15185:2016 standards.

In this study, SPSS (Statistical Package for the Social Sciences) was used to determine the correlation between Temperature, BOD (Biochemical Oxygen Demand), and DO (Dissolved Oxygen) using Pearson's correlation coefficient. Additionally, it was used to analyze the correlation between pH, Alkalinity, Turbidity, TSS (Total Suspended Solids), and TDS (Total Dissolved Solids), helping to understand their interdependence. Furthermore, the mean and standard deviation of pH, Turbidity, Alkalinity, TSS, and TDS providing the insights into data variability. Pearson Correlation Analysis was also conducted to examine the strength and direction of relationships between pH, Turbidity, Alkalinity, TSS, and TDS, aiding in environmental assessment and water quality evaluation.

2. RESULTS AND DISCUSSION

3.1 Water Quality Parameters: Water was collected from various places as mention above. The Water Quality Parameters of the collected sample were compared with WHO and Indian Drinking Water Standards (IS: 10500) and summarized in Table.2. The colour of Asan River water was highly turbid in pre-monsoon season and the colour of water is of light brown to dark brown on some places, clay type of colour is due to presence of dissolved organic matter that is unfit for drinking and out of specification according to WHO and ISI water should be clean and clear for drinking.

3.1.1 pH: The results reveals that the pH levels of collected water samples i.e. 7.84, 7.9, 8.00, 8.12, and 7.5, for S-01, S-02, S-03, S-04 and S-05 respectively of Asan River are in the desirable and permissible limits demonstrated by WHO and the Indian Standard Specifications for Drinking Water (IS:10500). The pH do not have negative impact on fitness or well-being, but its excessive amount push the development of scale in heat system and as well as lower down antiseptic prospects of chlorides. Excessive level of pH be the cause of development of harmful trihalomethanes (Kumar et al. 2010). Singh et al. (2019) noticed the pH varies from 6.52-7.18 which is neutral in nature.

3.1.2 Temperature: The result shows the temperature of Asan River water varies from 19.2 to 20.6 ^{0}C which is similar to the previous noticed variation of 18.6 and 20.8°C on Potable Water of Eastern Himalayan State Sikkim (Singh et al 2019). Temperature is most significant parameter as it is influence by the physical, chemical and biological characteristics of water and its chemistry. Some of the previous shows that the temperature never remains constant in rivers due to changes in the environmental conditions (Kumar, 2010). A study on pollution status and its impact on water quality of Ganga River at Haridwar (Khanna et al., 2011).

3.1.3 Turbidity: The present study shows the variation of turbidity significantly from sample S-01 (12 NTU) to S-05 (30 NTU). These values exceed both the desirable and permissible limits, indicating potential concerns regarding water quality and the need for effective filtration and treatment before consumption. The reasons for turbidity according to which participates to clarity of water like soli decay, high fertilizers encourages fungi growth, garbage extraction and large number of ground feeds that interferes with wastewater. High Turbidity also stops the dissolved oxygen enclosed in water. Coagulation, flocculation, sedimentation, and filtration are a few of the physicochemical treatment techniques that can be used to successfully lower turbidity in water. While flocculation helps the destabilized particles aggregate into larger flocs, coagulation is the process of adding chemical coagulants (such alum or ferric salts) to destabilize suspended particles. After being separated from the water by sedimentation, these flocs are filtered to get rid of any last bits of pathogens and tiny particles. By reducing runoff, encouraging the sedimentation of suspended particles, and improving infiltration, these systems lower turbidity and stop sediment-laden water from entering natural water bodies. Maintaining acceptable turbidity levels requires the blending of these biological and engineering approaches, particularly in areas where runoff from agriculture or cities is common.

3.1.4 Alkalinity: The Asan River's alkalinity recorded from station 1 to station 5 results in the between 110.2 to 129.6 during monsoon season, which shows water has higher amount of alkalinity than the permissible limits required, but lower than the required limits given by WHO and ISI. The presence of weak acid is measured by Alkalinity and also shows how much cation is balanced against them. The enzyme activities are also controlled by alkalinity which may be due to rainfall.

3.1.5 Total hardness (Calcium and Magnesium): The hardness of water is mainly caused by the deposition of calcium and magnesium due to high pollution level in water. The total hardness present in Asan River water during monsoon season between 162 to 220 mg/l which is acceptable by the standards of drinking water given by WHO and ISI. The both Calcium and Magnesium of Asan river water are measured by using complex metric titration method. The standard for drinking water for permissible limit is

75 and desirable limit given by WHO is 100mg/ml of calcium and the standard for magnesium in drinking water. Calcium concentrations were 53.2 to 67.8 and magnesium concentration were 18.2 to 23.7 mg/l during monsoon season which are in acceptable limit given by standards.

3.1.6 DO, BOD and COD: The quantity of organic compound that promotes the growth of microorganisms is measured by BOD. Strength and sewage power of pollution and another water pollutant gives the data about quantity of load of pollution in natural water. The result showed that the Asan River water in the monsoon period have D.O value 3.1 to 3.9ppm. It is in the range given ISI standard that is 4.0 ppm and the BOD is below 6.0 ppm a limit given by WHO and ISI standards. The amount of COD in Asan River water is analyzed by using open reflux method and the result showed that the water in the monsoon period have COD value between 2.1 to 3.8ppm, that are in permissible limits given by WHO and ISI standards. The TDS present in Asan River water during monsoon season between is in permissible range in all stations from S-1 to S-5 while TSS present from S-1 to S-5 is 521-863. In an analysis of physico- chemical and microbiological parameters, Kora et al. (2017) found that TDS levels throughout the dry season varied between 768.4 and 814.6 mg/L in August 2014 and 715.2 and 793.0 mg/L in September 2014. The study also noted that although these values were above the 500 mg/L Indian water quality standard, they were still within the WHO-recommended acceptable limits. Another study over on Gola, Ramganga and Saryu River Uttarakhand shows that TDS concentrations varied from 427 to 884 mg/l during the Pre-monsoon and from 127 to 344 mg/l during the Post monsoon season (Saxena et al.2023).

3.1.7 Chloride: The presence of chloride is the estimation of organic waste matter. The study shows the Chloride presence which ranges between 19.4 to 37.2 mg/l which is quite low as compared to the acceptable limit given by WHO and ISI. The contemporary results of Asan River are in agreement with the findings over three significant Kumaun Himalayan rivers—Gola, Kosi, and Ramganga conducted by Saxena (2021) during pre-monsoon (i.e. 14.8 mg/l to 40.3 mg/l) and post-monsoon season (i.e. 10.2 mg/l to 14.7 mg/l). The irrigation runoff, seawater intrusion, and the weathering and dissolution of salt deposits are the prime factors for the availability of Chloride in the water. In addition to giving water a salty flavor, high chloride levels can raise the risk of kidney stones, asthma, osteoporosis, and hypertension.

3.1.8 Sulphates and Nitrates: The sulphate content in Asan river water analyzed by using titration method results the concentration of sulphates content present in Asan river water is 31.6 to 39.9mg/l within required and permissible limit according to WHO and ISI. Results showed that the content of Nitrate present in Asan river water in monsoon season is 2.2 to 3.3mg/l that is within the acceptable range given by of WHO and ISI standard. WHO (1985). The study by Saxena (2021) shows the mean concentration ranged from 4 to 16 mg/l (pre-monsoon) and from 6 to 61.95 mg/l (post-monsoon), respectively. Although sulfate is normally non-toxic, healthy people may experience digestive problems if they drink water that has high levels of sulphate.

3.1.9 Flouride: The content of fluoride present Asan river water between 0.58 to 0.72 mg/l present in the monsoon period that are within the range given by of WHO and ISI standard. Different components like mica and apatite that released into water by wastes from different sources release fluoride in water and turn it into pollution. Commonly fluoride affects skeleton and dental health (Mahesh et al. 2012). The study conducted by Unnisa et al. (2021) over the Purna River, Maharashtra shows the Flouride concentration i.e. 0.37 mg/litre (monsoon) and maximum 0.73 mg/litre (summer).

3.1.10 Sodium and potassium: The sodium content present in Asan river water was analyzed by using flame-photometer and the result showed that the sodium content present in Asan River water in the monsoon period have normal value within the range given ISI standard that is 4.0 ppm. The amount of potassium present in Asan River water is also analyzed by using flame-photometer and the result showed that water of Asan river have 5.8 to 7.2 mg/l content of potassium in the monsoon period that is not within the range given by of WHO that and ISI standard which is 1.2. There were no contaminations of Ammonia, Phenol, Surfactants, Sulphide, Iron, Lead, Mercury and no other biological contamination such as Total bacteria count, E.Coli and Coliform was recorded throughout the study period. In Many other research finding were also of same kind with similar observation (Sharma et al. 2015, Matta et al. 2018a, 2018b, 2018c, 2018 d). In the current study, urban land use generated significant fecal bacteria in the dry season, demonstrating an increase in coliform concentration found in warm wet seasons. Higher temperatures and increased rainfall with more runoff events both contribute to higher fecal coliform counts during the wet season (Kim et al. 2017).

Figure 3 demonstrate the correlation between Temperature, BOD, and Dissolved Oxygen (DO) through the Pearson's correlation coefficient. The results shows a sturdy negative correlation between Temperature and BOD ($r = -0.811$). The correlation coefficient of -0.811 between temperature and biochemical oxygen demand (BOD) indicates a strong negative relationship, suggesting that as temperature increases, BOD tends to decrease. This inverse correlation may be attributed to enhanced microbial activity at higher temperatures, leading to faster decomposition of organic matter and a reduction in measured BOD levels. Water contaminated with faecal matter appears to be the major source of microbial pollution in the environment across the globe (Hamiwe et al. 2019; Ball et al. 2021). While Yang et al. (2020) note that microbial pollution is a major global problem as it is a human health concern and a significant health hazard to the ecosystem. Furthermore, various studies have reported the presence and/or likelihood of pathogenic traits in faecal-indicator bacteria (Burnet *et al.* 2021).

Additionally, elevated temperatures can decrease oxygen solubility in water, further influencing BOD dynamics. Conversely, the correlation between Temperature and DO (r=0.165), shows a weak relationship, indicating a moderate increase in DO with rising temperature. Additionally, BOD and DO exhibit a weak correlation (r=0.210), implying a minor correlation between these two parameters. These findings offer insights into the interdependencies of key water excellent indicators and their capability implications for aquatic ecosystems.

Figure 4 shows the Correlation between PH, Alkanity, Turbidity, TSS and TDS. The correlation analysis of pH with various water quality parameters reveals distinct relationships. pH exhibits a moderate negative correlation with turbidity (r = -0.455) and total dissolved solids (TDS) (r = -0.362), indicating that an increase in turbidity or TDS is associated with a decrease in pH. Conversely, a weak positive correlation is observed between pH and total suspended solids (TSS) (r = 0.190), suggesting a minimal influence of TSS on pH variations. Additionally, pH shows an insignificant correlation with alkalinity (r = 0.027), implying little to no direct relationship between these parameters. These findings highlight the complex interactions between pH and key water quality indicators.

The observed moderate negative correlation between pH and Turbidity (-0.455) suggests that as turbidity increases, pH tends to decrease. This can be attributed to the presence of suspended particulate matter, such as organic debris and clay particles, which often carry acidic substances. Additionally, high turbidity can indicate microbial activity, leading to the production of acidic byproducts that lower pH. The weak positive correlation (0.190) between pH and Total Suspended Solids (TSS) suggests that TSS has a minimal effect on pH. This may be due to the diverse nature of suspended solids, which include both acidic and alkaline particles. Depending on the composition, TSS can either buffer pH changes or contribute to minor fluctuations in pH levels.

The moderate negative correlation (-0.362) between pH and TDS indicates that higher concentrations of dissolved solids, including salts, metals, and organic compounds, may contribute to pH reduction. This is likely due to the dissolution of acidic compounds such as sulfates, nitrates, and carbon dioxide, which can lower the pH of the water. In industrial and agricultural areas, elevated TDS levels are often associated with increased acidity, further reinforcing this trend. The insignificant correlation (0.027) between pH and alkalinity suggests that alkalinity alone may not be a primary factor controlling pH variations in the studied water samples. While alkalinity is a measure of a water body's ability to resist pH changes (buffering capacity), the presence of other acidic or basic compounds could be overriding its effect, leading to a weak overall relationship.

Turbidity can be reduced through coagulation, flocculation, sedimentation, and filtration, while constructed wetlands and buffer zones help limit sediment-laden runoff. Elevated sodium and potassium, often from agriculture, industry, or natural sources, can be managed through source control, reduced fertilizer use, and organic farming. For drinking water, ion-exchange or reverse osmosis may be used. These measures enhance water quality, safeguard public health, and protect aquatic ecosystems from long-term harm.

Table 3 shows that most of the parameters have quite low standard deviations, implying that there is little variation in the quality of the water. The largest variance, though, is chloride concentration (7.609), which indicates other factors such as industrial waste and agricultural fertilizer runoff could be contributing to these differences. The water hardness (287.00 ± 10.112) is still acceptable for drinking water, and the source of hardness is corroborated by calcium and magnesium being present. Because the nitrate concentration (2.74 ± 0.445) is lower than the critical limit, there is a smaller likelihood of health complications. The fluoride concentration (0.64 ± 0.061) is also within the acceptable limits recommended for aiding in the preservation of dental health.

3.2 FIGURES AND TABLES

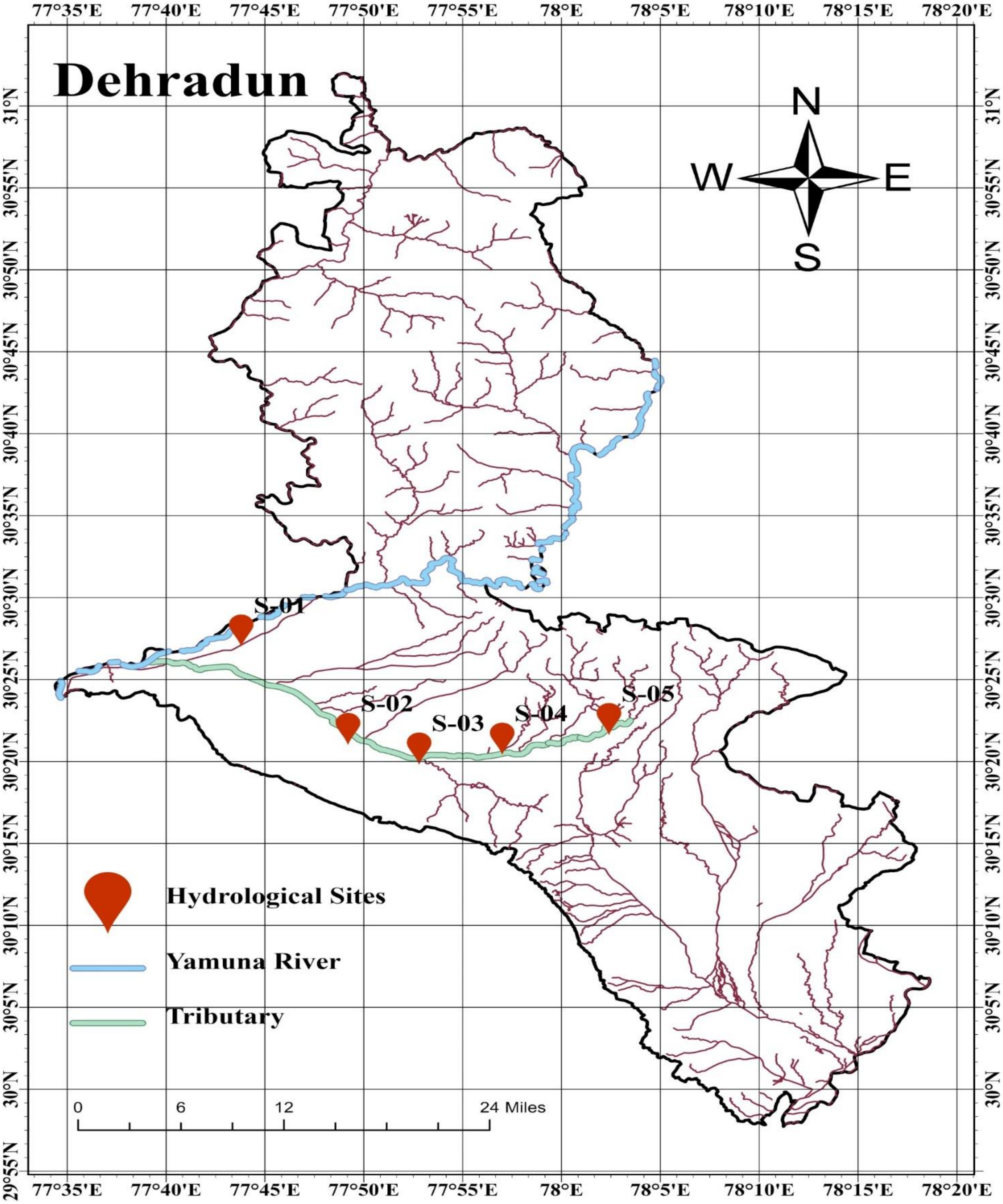

Figure 1.The satellite image of the Asan River and the streams flow into it.

Figure 2: Sampling locations along the Asan River – Sample 1 (S-01) at Herbertpur Asan Bridge, Sample 2 (S-02) at Rampur, Sample 3 (S-03) at Dhoolkot, Sample 4 (S-04) at Premnagar, and Sample 5 (S-05) at Gajiyawala (Birpur).

Table.1 List of various Laboratory tests with their Reference.

S. NO.	**Name of Parameter**	**Equipment used**	**References**
1.	Colour	spectroscopic method	APHA -2120C
2.	Temperature	Thermometer	APHA - 2012
3.	Odour	Olfactometer	APHA -2150B
4.	Ph	pH meter	APHA -4500 B
5.	Turbidity (NTU)	Nephlometric meter	IS: 3025(P-10:1984)
6.	Alkalinity	Titration	APHA -2320B
7.	Total Hardness	EDTA Titrimetric Method	APHA -2340C
8.	Calcium as Ca (mg/l)	EDTA Titrimetric Method	APHA -3500

9.	Magnesium (mg/l)	EDTA Titrimetric Method	APHA -3500
10.	Ammonia (mg/l)	Ammonia Distillation Flask	IS: 3025(P- 34):1998
11.	BOD (mg/l)	5-Day BOD Test Method	APHA -5210B
12.	TDS (mg/l)	Total Dissolved solids Dried at 1800C Method	APHA-2540C
13.	TSS (mg/l)	TSS Dried at 103-1050 C Method	APHA 2540D
14.	Chlorides (mg/l)	Titration	IS:3025(P-32):1988
15.	Sulphates (mg/l)	Turbidimetric Method	IS: 3025(P- 24): 2022
16.	Nitrate (as NO3-) (mg/l)	Spectrophotometer	IS: 3025(P- 34): 1988
17.	Fluoride(mg/l)	Spectrophotometer	APHA 4500 F.D. 24th edition
18.	Iron (mg/l)	ICP-MS	IS: 3025(P- 65): 2022
19.	Phenol (mg/l)	Spectrophotometer	IS: 3025(P- 43): 2022
20.	Sulphide (as H2S) mg/L	Test tube	IS: 3025(P- 29): 1986
20.	Surfactants(Anionic) (mg/l)	Spectrophotometer	Annex, KoF IS:13428-2005
21.	Sodium (as Na+)	Flame Photometer	IS: 3025(P- 45- 1993)
22.	Potassium (as K+)	Flame Photometer	IS: 3025(P- 45- 1993)
23.	DO	Winkler’s Iodometric method	APHA 4500-O B
24.	COD	Open Reflux Method	APHA 5220B
25.	Lead	ICP-MS	IS: 3025(P- 65): 2022
26.	Mercury	ICP-MS	IS: 3025(P- 65): 2022
27.	Electrical Conductivity	Electrical conductivity meter	APHA 2510B
28.	Total bacteria count/100ml	Filtration Assembly and Incubator	IS 5402(P-1) :2021
29.	E.Coli /100ml	Filtration Assembly and Incubator	IS 15185:2016
30.	Coliform per 100ml	Filtration Assembly and Incubator	IS 15185:2016

Table 2. Comparison of water quality parameters with WHO and Indian Drinking Water Standards (IS:10500)

S NO.	Name of Parameter	Requirement desirable limit	Permissible limit (WHO Standard)	Indian Standard Specifications for Drinking water IS:10500	S -01	S-02	S-03	S-04	S-05
1.	Color	5	Colorless	May be extended up to 15 if toxic substances are suspended	Turbid	Turbid	Turbid	Turbid	Turbid
2.	Temperature	-	-	-	20.6	20.4	20.2	19.6	19.2
3.	Odour	Agreeable	Agreeable	Agreeable	NO smell	Rotten smell	No smell	Pungent smell	No smell
4.	Ph	6.5 to 8.5	6.5 – 9.2	May be relaxed up to 9.2 in absence	7.84	7.9	8.00	8.12	7.5
5.	Turbidity (NTU)	1	-	May be relaxed up to 5 in absence of alternate	<1.0	12	15	18	30
6.	Alkalinity (mg/l)	100	250		128.8	110.2	114.4	129.6	122.4
7.	Total Hardness	300	400	May be extended up to 500	288.5	273.5	280.8	292.9	299.3
8.	Calcium as Ca (mg/l)	75	100	May be extended up to 200	68.7	67.8	69.1	69.3	72.2
9.	Magnesium (mg/l)	30	150	May be extended up to 100	28.4	25.3	26.3	29.1	28.9
10.	Ammonia	0.5	0.5	No relaxation	BLQ	BLQ (0.1)	BLQ	BLQ	BLQ

	(mg/l)				(0.1)		(0.1)	(0.1)	(0.1)
11	BOD (mg/l)	30	6.0	May be extended up to 100	2.75	3.25	3.7	4.4	3.9
12.	TDS (mg/l)	500	500	May be extended up to 2000	260	289	293	326	349
13.	TSS (mg/l)	500	500	May be extended up to 2000	696	521	789	821	863
14.	Chlorides (mg/l)	250	500	May be extended up to 1000	19.7	19.8	19.4	24.3	37.2
15.	Sulphates (mg/l)	200	400	May be extended up to 400	38.2	32.1	31.6	39.2	39.9
16.	Nitrate (as NO3-) (mg/l)	45	45	No relaxation	2.8	2.2	2.4	3.0	3.3
17.	Fluoride(mg/l)	0.6 to 1.2	1.5	If the limit is below 0.6 water should be rejected, max limit is extended to 1.5	0.64	0.58	0.59	0.69	0.72
18.	Iron (mg/l)	0.3	1.0	No relaxation	BLQ (0.05)	BLQ (0.05)	BLQ (0.05)	BLQ (0.05)	BLQ (0.05)
19.	Phenol (mg/l)	0.5	0.002	-	BLQ (0.001)	BLQ (0.001)	BLQ (0.001)	BLQ (0.001)	BLQ (0.001)
20.	Surfactants(Anionic) (mg/l)	0.2	-	May be relaxed up to 1.0	BLQ (0.2)	BLQ (0.2)	BLQ (0.2)	BLQ (0.2)	BLQ (0.2)
21.	Sodium (as Na+)	20 mg/ltr	6.5	No relaxation	30.2	28.6	28.3	32.6	34.8

22.	Potassium (as K+)	1.2	1.2	No relaxation	6.8	5.9	5.8	6.9	7.2
23.	DO	5	NA	May be extended up to 10	3.1	3.4	3.9	3.3	3.2
24.	COD	4.0	NA	4.0	3.2	3.8	2.8	2.1	3.5
25.	Lead	0.05	0.1	0.01	BLQ (0.01)	BLQ (0.01)	BLQ (0.01)	BLQ (0.01)	BLQ (0.01)
26.	Mercury	0.001	0.001	0.001	BLQ (0.001)	BLQ (0.001)	BLQ (0.001)	BLQ (0.001)	BLQ (0.001)
27.	Electrical Conductivity	300µS/cm	300µS/cm	-	133.3	131.2	130.5	133.9	135.2
28.	Total bacteria count/100ml	100	100ml	No relaxation	11	08	09	10	09
29.	E.Coli /100ml	100	10/100ml	No relaxation	Absent	Absent	Absent	Absent	Absent
30.	Coliform per 100ml	1x100000	-	No relaxation	Absent	Absent	Absent	Absent	Absent

Table 3. Mean and Standard Deviation of various parameters of collected water samples.

Parameter	**Mean**	**Std. Deviation**
Hardness	287.00	10.112
Calcium	69.42	1.657
Magnisium	27.60	1.700
Chloride	24.08	**7.609**
Sulphate	36.20	4.021
Nitrate	2.74	0.445
Fluride	0.64	0.061
Sodium	30.90	2.768

Potasium	6.52	0.630
Conductivity	132.82	1.941

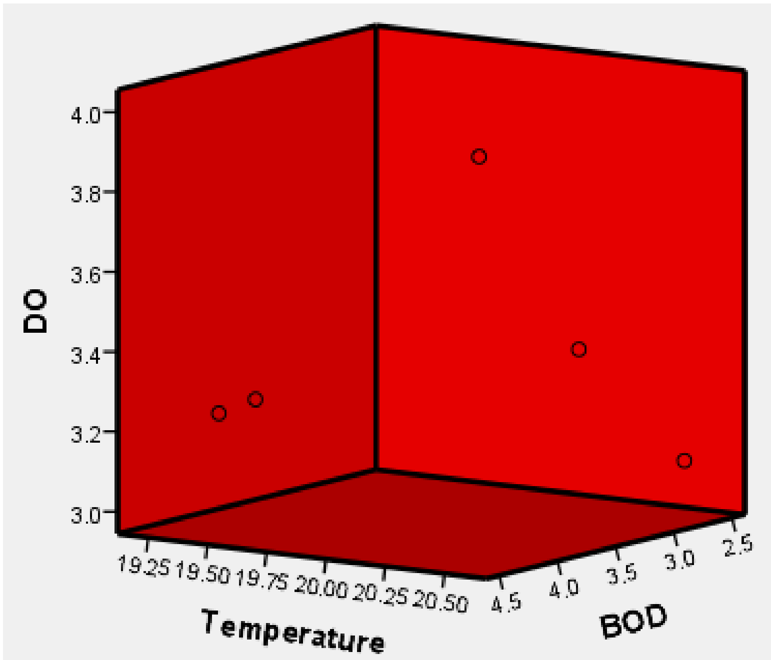

Figure.3 Correlation between Temperature, BOD and DO

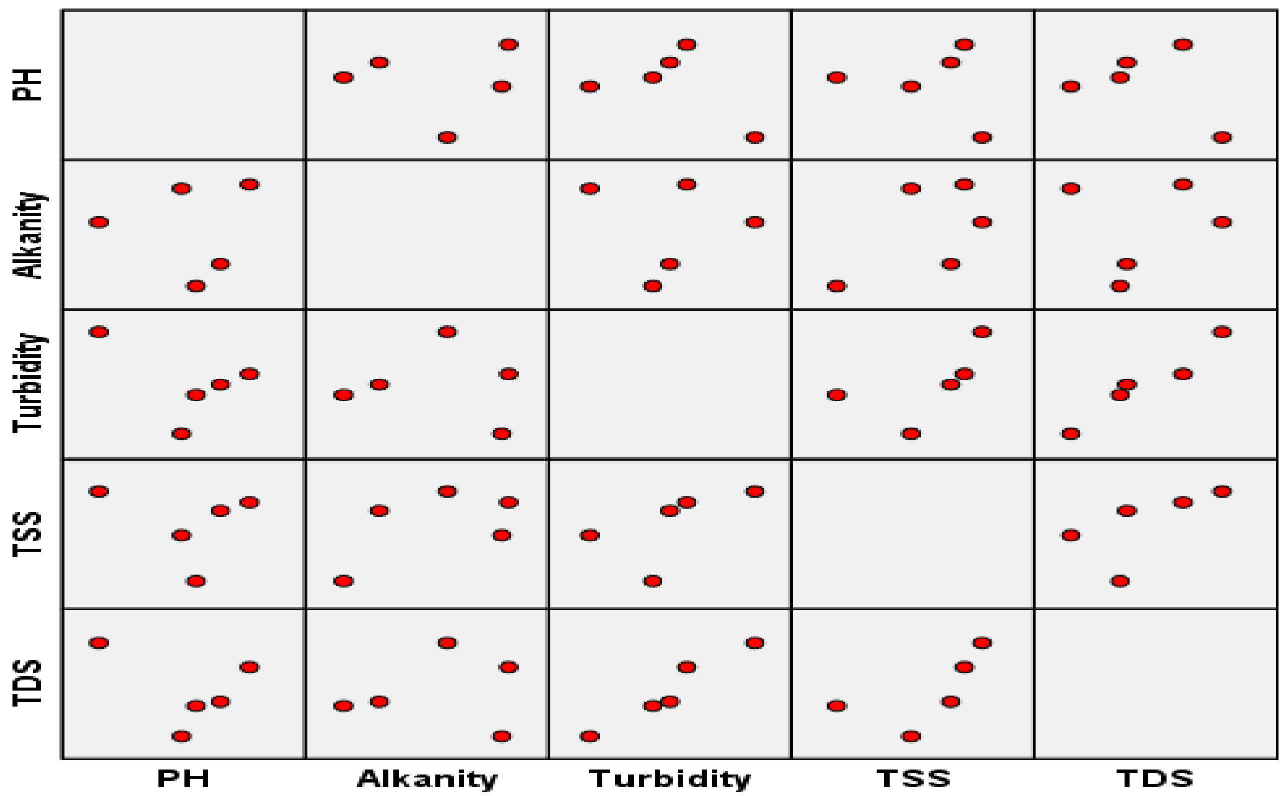

Figure 4. Correlation between PH, Alkanity, Turbidity, TSS and TDS.

3. CONCLUSION

The study was conducted on the Asan River in the district of Dehradun, Uttrakhand, India. The measurement of thirty different parameters which are compared to WHO (World Health Organization) and ISI (Indian Standard Institution mark), permissible and required limits and the result shows that all measured parameters are in the acceptable limit except the turbidity and Sodium and potassium that are far beyond the acceptable limit and are responsible to increase the water quality index.

The study shows that most of the parameters have quite low standard deviations, implying that there is little variation in the quality of the water. The high turbidity is caused naturally (Rain, snowmelt and erosion), by humans (construction, mining, agricultural runoff, industrial discharges, and urban run-off) and Untreated wastewater (carry pathogens, suspended solids, and other contaminants into water body) and high level of sodium and potassium in rivers caused by Weathering of rocks, Wastewater disposal, Agricultural land use, Municipal and industrial sewage discharges, Leaking subsurface sewers. In the Asan River the water quality index indicates that due to the higher concentration of turbidity, sodium and potassium makes the water undesirable for any use, especially drinking, irrigation and industrial use and it can have many bad impact on life on and inside the river such as too much consumption of it also cause high blood pressure, heart and kidney disease and irregular heartbeat and even can be the reason for heart attack many times. So, adequate using a low possibility of either long or short-term damage, a proper care or treatment is become essential. With regards to the fluctuated data, shows that the Asan River required attention and monitoring physical chemical parameters and water quality index. Further, these activity helps in increasing public consciousness that the need to safeguard the quality of Asan River water. In short, the consumption of water which does not have been adequately purified is usually recommended. The correlation trends suggest that factors such as sediment load, dissolved ions, and organic matter significantly influence pH variations in water. The negative correlation with turbidity and TDS highlights the potential impact of pollution, erosion, and industrial effluents on water acidity. Meanwhile, the weak relationships with TSS and alkalinity indicate that pH changes may be governed by a combination of multiple factors rather than a single dominant parameter. Further investigation, including seasonal variations and site-specific influences, could provide deeper insights into these interactions.

When compared with similar river systems in Uttarakhand, such as the Ganga at Rishikesh or the Kosi and Saryu rivers in the Kumaon region, the Asan River exhibits some notable deviations in water quality parameters, particularly with elevated turbidity, sodium, and potassium levels. Studies on the Ganga and its tributaries typically report turbidity within permissible limits during non-monsoon periods due to higher flow volumes and better self-purification capacities. In contrast, the Asan River—being a smaller and slower-flowing tributary—appears more vulnerable to localized anthropogenic influences, such as untreated domestic discharges, agricultural runoff, and sediment input from soil erosion. Similar patterns have been observed in smaller rivers like the Hindon in western Uttar Pradesh and the Yamuna near Delhi, where reduced flow and high pollutant loads exacerbate water quality degradation. These comparisons underscore the unique sensitivity of the Asan River system and reinforce the need for localized, watershed-specific management strategies.

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Conflicts of Interest:

There is no skirmish of interest in authorship.

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