Evaluation of Seasonal Variations and Water Quality Index at Seti River, Pokhara

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Abstract

Purpose: This research investigates the seasonal variations of the Seti River during the dry and wet seasons.
Methods: Water samples were collected from two sample locations (n = 3) between April 2024 and July 2024 representing both wet and dry seasonal conditions. The physiochemical parameters analyzed were pH, Total Suspended Solids, Electric Conductivity, Dissolved Oxygen, Phosphate, Nitrate, Ammonia, Biochemical Oxygen Demand, and Total Hardness using American Public Health Association (APHA) methods. Water Quality Index (WQI) was determined to evaluate the status of water quality during the dry and wet seasons.
Results: Concentration of various physiochemical parameters were analyzed and significant differences in all physiochemical parameters were observed. Five parameters (pH, Total suspended solids, Total hardness as $CaCO_3$, Ammonia and Dissolved oxygen) showed their maximum level during wet season. Other parameters (Electric conductivity, Nitrate, Phosphates and Biochemical oxygen demand) showed their highest value during dry season. The calculated WQI for Hemja and Patneri during dry and wet seasons were 66.1, 44.9, 84.5 and 77.6, respectively.
Conclusion: The analysis of the results indicates a gradual decline in the quality of Seti river. It is worsened, mainly during the rainy season as the river receives increased loads of contaminants including agricultural and surface runoff.

Keywords: Dry season; Physiochemical parameters; River water; Wet season; Water quality index

1 Introduction

Water is a basic requirement for the existence of all living organisms and is used in various applications as irrigation, domestic and sanitation purpose. The river water quality worsening is mainly due to human activities such as discarding of dead bodies, expulsion of industrial and sewage wastes and agriculture runoff. Waste material also damped in river which directly affects the organic matter concentration in downstream of river. Moreover, residual industrial wastes often contributes to the contamination of heavy metals in the environment which are toxic to humans health (Paul, 2017). Due to this, a growing concern about water scarcity and the need to address future water demand has forced all countries worldwide to evaluate the current state of river water quality and monitor pollutions levels (Chen et al., 2019; Mekonnen & Hoekstra, 2016).
World Health Organization (WHO) has estimated that upto 80% of illness and diseases globally is caused by insufficient sanitation, environmental pollution or less availability to safe drinking water. Contaminated drinking water and poor sanitation are linked to transmission of disease such as cholera, diarrhea, dysentery and polio (Maharaj & Maharaj, 2021; Rajendrakumar et al., 2025). Therefore, to address these issues, the United Nations has designated Sustainable Development Goal 6 (SDG 6), "Ensure availability and sustainable management of water and sanitation for all", to enhance water quality and improve sanitation management worldwide (Singh & Jayaram, 2022).

Rivers in Pokhara serves as the primary water source for livestock farming, aquaculture, industries, irrigation, and wastewater dilution. The Seti River flows near the Pokhara Industrial Estate, which has various manufacturing units like textiles, metal works, and food processing industries, are known to discharge untreated or partially treated wastewater into the Seti River. Monitoring and management of surface water is a critical concern due to direct discharge of untreated industrial and commercial wastewater into these rivers. Accurate and reliable water quality data are essential for the sustainable management, protection, and development of surface water resources (Bhat & Qayoom, 2021).
Seasonal variations significantly affect water quality, especially in agricultural regions. During dry seasons water resources are stressed due to increased demand often leading to deteriorated water quality. In contrast, wet season receives heavy rainfall which contribute to increased agricultural runoff. Therefore, water quality analysis is crucial to assess the suitability of a water sources for the designed use.
This study aims to assess pollutant concentrations of Seti River and determine its WQI during dry and wet seasons. The WQI is a numerical representation of overall water quality which provides a clear and simplified for public understanding. It is an important parameter for evaluating pollution control initiatives and water resource management. In general, various water quality parameters are incorporated into a mathematical equation that evaluates the health of the waterbody and assigns it a corresponding index value (Abdul Maulud et al., 2021). Common methods for calculating WQI include the National Sanitation Foundation Water Quality Index (NSF WQI), the Weighted Arithmetic Water Quality Index (WAWQI), the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) and the Namerow Pollution Index (NPI) (Islam, 2024).
In this study, 9 water quality parameters such as Conductivity, pH, TSS, BOD, DO, Phosphate, Ammonia, Nitrate, Total Hardness as CaCO3 were analyzed and interpreted to understand the pollution level of Seti River. Their obtained values were compared with WHO recommended value and WQI was calculated.

2 Materials and methods

2.1 Study area

Pokhara, the capital of Gandaki Province and the largest metropolitan city of Nepal, is situated within a subtropical climate zone (Rai, 2000). The monsoon season which starts from June and ends in September, brings heavy rainfall with annual precipitation averaging around 3,500 mm. It covers an area of 464.24 km^2 (179.24 sq mi) and has a population of 5,13,504 individuals according to 2021 AD (2078 BS) Nepal census. Geographically, it is situated at 28° 13' N latitude and 83° 57' E longitude with altitude ranging from 827 m (2,713 ft.) to 1,740 m (5,710 ft.) above sea level. The city is divided into 33 wards.
In this region, the elevation rises approximately from 1,000 m (3,300 ft) to 7,500 m (24,600 ft) within the range of 30 kilometres (19 miles). As a result of this steep topographical variation, this region has one of the highest precipitation rates in Nepal (Dhakal et al., 2024). Moreover, rainfall pattern within Pokhara vary noticeably, with the northern areas at the foothills of the mountains receives higher precipitation compared to the South. Figure 1 shows the map of Pokhara Metropolitan City along with sampling locations.

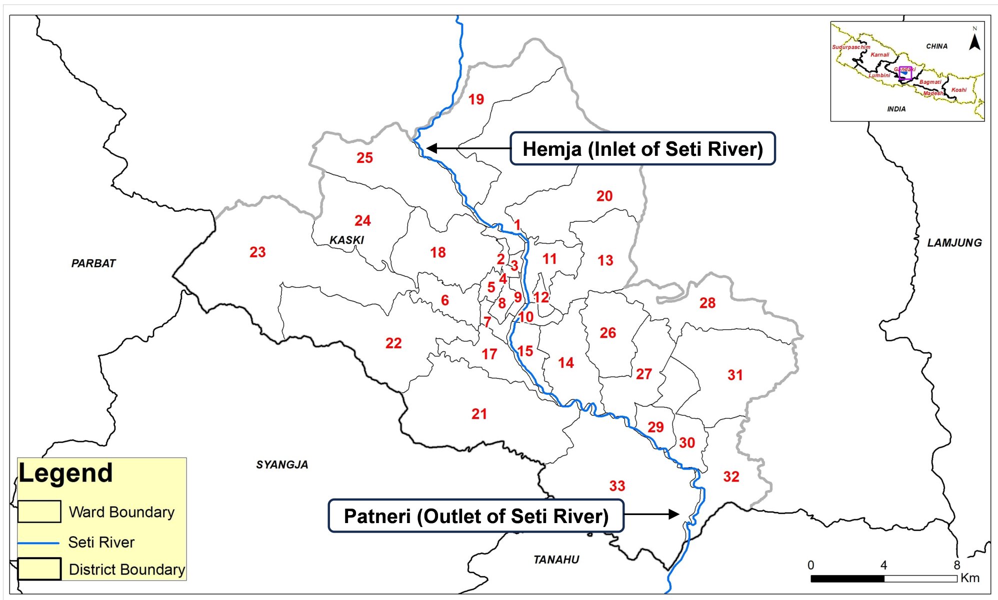


Figure 1: Map of Pokhara Metropolitan City with sampling location (Data source: Survey department of Nepal).

2.2 Sample collection

The water samples were collected twice a year – dry season (April) and wet season (July). Three bottles per sample was collected at two different points for different quality parameters studies – one sample from northern part from where Seti River enters Pokhara Metropolitan City (Hemja) and another sample from southern part from where Seti River leaves Pokhara Metropolitan City (Patneri). Before the sample collection, the bottles were thoroughly washed with tap water and rinsed with distilled water. The test bottle was labeled with sample site and date.

2.3 Sample analyses

The analysis of all samples was conducted according to the Standard Methods for the examination of Water and Wastewater. The pH was determined using a portable digital pH meter. Conductivity of water samples was measured on-site using a digital conductivity meter and the reading were noted in terms of µS/cm. Dissolved oxygen was determined by Iodometric method and five days BOD test was performed to calculate biochemical oxygen demand. Similarly, total hardness of water was determined by EDTA titrimetric method, ammonia by phenate method, nitrate by phenol disulphonic method and phosphate by stannous chloride method.

2.4 Water Quality Index (WQI) calculation

WQI is a numerical value derived through mathematical transformation of large quantities data of water quality (Kannel et al., 2007). The calculation of WQI is performed using the Weighted Arithmetic Index Method (Islam, 2024) which involves several steps outlined below:
Step 1: Use formula to calculate the unit weight (Wn) values for each parameter.

$$W_n = \frac{K}{S_n}$$

where,
$W_n = \frac{K}{S_n}$ where $K = \frac{1}{\frac{1}{S_1} + \frac{1}{S_2} + \frac{1}{S_3} + \cdots + \frac{1}{S_n}} = \frac{1}{\sum_{i=1}^{n} \frac{1}{S_i}}$

S_n = Desirable standard value of the nth parameter.

$W_n = 1$ (unity) when all selected parameter unit factors are added together.

Step 2: Determine the sub-index (Qn) by using the following equation:

$$Q_n = \frac{(V_n - V_o)}{S_n - V_o} * 100$$

where,
V_n = mean concentration of nth parameters

S_n = Desirable standard value of the nth parameters

V_o = Real values of parameters in clean water (generally V0=0, for most parameters except for pH=7 and DO=14.6)

Step 3: Combining steps 1 and 2, WQI calculate as follows:

Overall WQI=$\frac{\sum W_n Q_n}{\sum W_n}$

3 Results

Evaluating water quality is important to ensure the suitability and long-term viability of water resources for human consumption and various other applications. Table 1 presents the physico-chemical properties of water samples from two different locations along the Seti River analyzed during the dry and wet seasons. The parameters analyzed include pH, total suspended solids, total hardness as CaCO3, Electrical conductivity, Ammonia, Nitrate, Phosphorus, Dissolved Oxygen and Biochemical oxygen demand.

Table 1: Concentration of physiochemical parameters from different locations of Seti River.

S.N.	Parameters	Units	Average Results (n = 3)				WHO standard
			Hemja (dry)	Hemja (wet)	Patneri (dry)	Patneri (wet)	
1	pH	–	7.5	7.8	7.4	8.0	6.5 - 8.5
2	Electrical Conductivity	µS/cm	291.0	218.6	293.0	199.4	1000
3	Total Suspended Solids	mg/L	45.5	143.0	21.8	130.0	20
4	Total Hardness as CaCO3	mg/L	124	781	176	909	500
5	Total Ammonia as N	mg/L	0.02	0.10	0.02	0.10	1.5
6	Nitrate as NO3.	mg/L	3.89	0.15	4.52	0.10	50
7	Phosphates as P	mg/L	0.38	0.01	0.1	0.01	5
8	Dissolved Oxygen (DO)	mg/L	5.4	9.1	4.8	8.2	6
9	Biochemical Oxygen Demand (BOD5)	mg/L	57.3	1.5	22.5	1.3	2

WHO = World Health Organization.

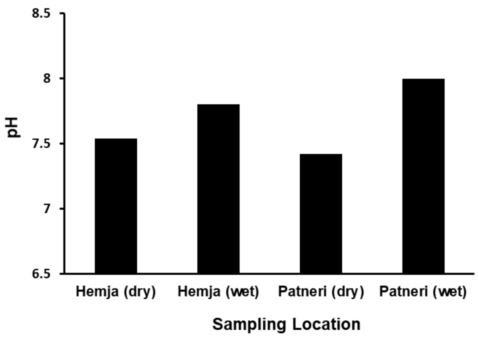
3.1 Physiochemical parameters

3.1.1 pH

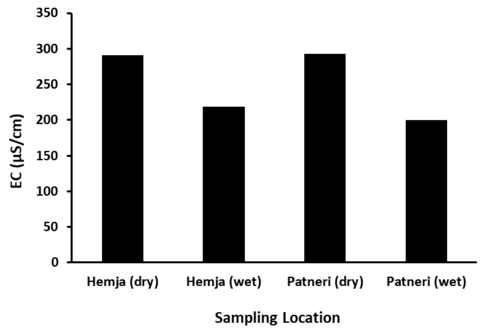
It is an important parameter for evaluating water quality, as it directly influences the survival of aquatic organisms (E. Daniel & U. Matthew, 2016). In the Seti River, pH measurements across all sampling stations ranged from 7.5 to 8.0 during both the dry and the wet seasons, aligning with the typical pH range of 6.5 to 8.5 observed in freshwater ecosystems (Figure 2a). Deviations from this range can have significant consequences such as pH levels below 6.5 may disrupt the synthesis of vitamins and minerals in the human body, while higher than 8.5 can impart a salty taste to water. Furthermore, pH levels above 11 can cause negative health effects, such as eye irritation and skin disorders. Differences in pH values observed in our study during the dry and rainy seasons is due to water runoff from surrounding soils, vegetation, and rocks which often contains basic (alkaline) substances, such as minerals like calcium carbonate ($CaCO_3$) from limestone or other alkaline soils.

3.1.2 EC

The result reveals that electron transfer efficiency is significantly higher during the dry season than the wet season. As observed in Figure 2b, the maximum average conductivity value (293 µS/cm) was recorded at the Patneri site during the dry season, while the minimum average value (199 µS/cm) was observed at the same location during the wet season. Higher EC values observed during the dry season is due to the discharge of wastewater from urban and industrial areas (Shoeb et al., 2022).



(a) Seasonal variation of pH at Hemja and Patneri during dry and wet season.



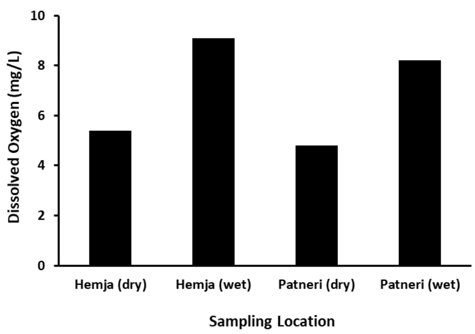
(b) Seasonal variation of EC at Hemja and Patneri during dry and wet season.

Figure 2: Seasonal variation of pH (a) and EC (b) at Hemja and Patneri during dry and wet season.

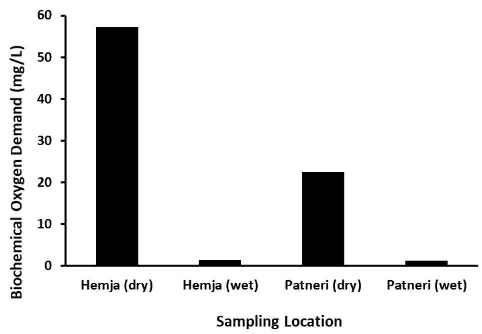
The average concentration of DO at Hemja and Patneri during dry season were 5.4 mg/L and 4.8 mg/L and during wet season were 9.1 mg/L and 8.2 mg/L, respectively. The analysis of water samples showed that the concentration of DO was found to be higher during the wet season as compared to dry season is shown in Figure 3(a).

3.1.3 BOD

From this study, the lowest average value of BOD (1.3 mg/L) was observed at Patneri during the wet season while the highest average BOD value (57.3 mg/L) was observed at Hemja during dry season. Figure 3(b) show the variation of BOD during dry and wet season.



(a) Seasonal variation of DO at Hemja and Patneri during dry and wet season.



(b) Seasonal variation of BOD5 at Hemja and Patneri during dry and wet season.

Figure 3: Seasonal variation of DO (a) and BOD5 (b) at Hemja and Patneri during dry and wet season.

3.1.4 Total Hardness as CaCO3

The maximum hardness was observed during wet season at Patneri (909 mg/L) and Hemja (781 mg/L), respectively. During dry season, the hardness of the Seti River was within the acceptable limit, as illustrated in Figure 4(a).

3.1.5 TSS

The highest average TSS value obtained was at Hemja (143 mg/L) during wet season. Higher TSS values observed during the wet season is due to wash out of contamination by water which can be seen from Figure 4(b).

3.1.6 PO_4-P

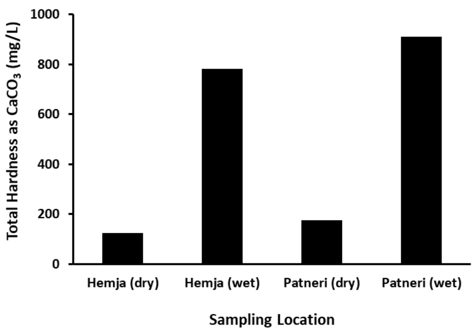
Analysis of water samples from various sampling locations revealed that the highest average phosphate (PO4-P) concentration (0.38 mg/L) was detected at the Hemja during the dry season. Higher phosphorus levels were indicative of potential eutrophication processes, with contributing factors likely including domestic wastewater discharge (containing detergents), agricultural runoff (fertilizers), and effluent from industrial activities (Hedjal, Zouini, & Benamara, 2018). Comparison of PO4-P during the dry and the wet season is shown in Figure 4(c).

3.1.7 NH_4-N

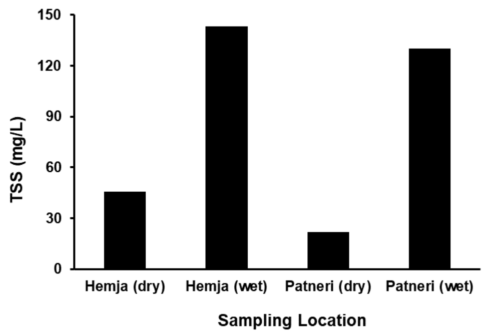
The concentration of NH4-N is relatively lower during dry season than in wet season as observed from Figure 4(d). High concentration of NH4-N detected in the Seti River during wet season was believed to be contributed from various anthropogenic sources such as agricultural runoff, livestock waste, and untreated domestic wastewater. The higher amount of NH4-N (0.1 mg/L) was found at Hemja and Patneri causing harm to aquatic life.

3.1.8 NO_3-N

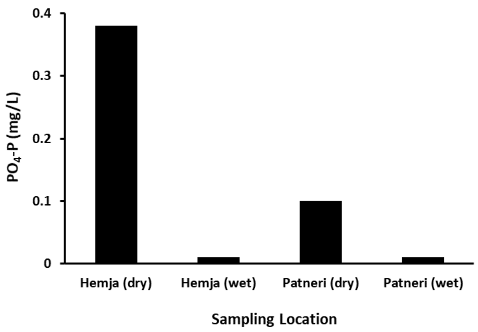
Highest average concentration of nitrate (NO3-N), 4.52 mg/L, was observed at Patneri during dry season as seen in Figure 4(e). During rainy season, nitrate concentrations were observed lower as compared to dry season which may be due to dilution of rainwater during washout.



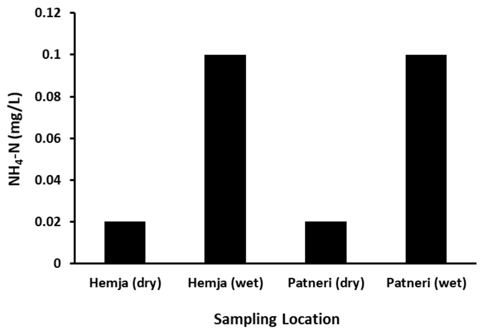
(a) Seasonal variation of Total hardness as CaCO3 at Hemja and Patneri during dry and wet season.



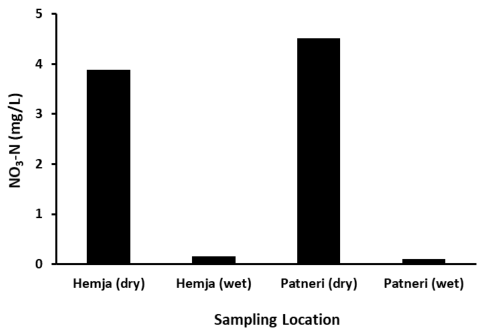
(b) Seasonal variation of TSS at Hemja and Patneri during dry and wet season.



(c) Seasonal variation of PO4-P at Hemja and Patneri during dry and wet season.



(d) Seasonal variation of NH4-N at Hemja and Patneri during dry and wet season.



(e) Seasonal variation of NO3-N at Hemja and Patneri during dry and wet season.

Figure 4: Seasonal variation of Total hardness as CaCO3 (a), TSS (b), PO4-P (c), NH4-N (d) and NO3-N (e) at Hemja and Patneri during dry and wet season.

4 Discussion

Water samples were collected during dry and wet seasons which correspond to different agricultural periods. In this study, ammonia and nitrates were found within the established maximum permissible limits. These parameters are frequently identified as contaminants in groundwater systems, primarily due to their high solubility in water and limited capacity for adsorption onto soil particles (Abascal et al., 2022). Although, nitrogen compounds such as ammonia and nitrates occur naturally in the environment, pollution of these compounds are often caused by the application of nitrogen-based fertilizers in agriculture, discharge of industrial effluents, and runoff from livestock manure. In aquatic systems, ammonia represents a predominant form of dissolved nitrogen and is recognized as a significant contaminant, adversely affecting reproductive success and growth rates in aquatic organisms. Due to its high permeability through the gill membranes, ammonia can accumulate in tissues, leading to neurotoxic effects and even death (Edwards et al., 2024; Ochs et al., 2024). The population residing near Hemja relies heavily on agricultural activities for their livelihood, which suggests the high concentration of ammonia and nitrate may be linked to runoff from farming practices.

DO is a crucial factor for aquatic species. The lower concentration of DO indicates higher level of water pollution. The lower values were observed during the dry season as compared to the wet season. One of the leading causes for reduced DO concentrations is due to the discharge of organic waste into water bodies (Zhu et al., 2024).

The BOD concentration is high during dry season which maybe because of the decomposition of organic matter from natural vegetation and other contributors such as runoff from construction sites, agricultural fertilizers, wastewater from septic systems, and livestock waste. BOD concentration is increased and DO concentration is decreased due to high concentration of organic pollutants in aquatic systems which lead to stressful environment for aquatic organisms. Continuous exposure of high BOD and low DO leads to respiratory distress and potential mortality of aquatic species in water (Susilowati et al., 2018).

The higher TSS concentration observed during the wet season was due to the high sediment yield due to suspended solids associated with the runoffs into the river (Yusoff et al., 2015). Similarly, high pH was observed during wet season due to the dilution of alkaline compounds and dissolution of atmospheric CO2 (Woldesenbet Worako, 2015). A similar study was performed on the physiochemical parameters of Chimdi lake located in Sunsari district of Nepal during wet season and found higher concentration of certain pollutants, such as TSS (210.846 mg/L) exceeding the permissible limit (Bishnu Dev, 2017).

Phosphate concentration during dry season was found 0.38 mg/L and 0.1 mg/L at Hemja and Patneri, respectively. However, low phosphate level (0.01 mg/L at both Hemja and Patneri) was observed during wet season. This could be due to dilution effect of the phosphate compounds for higher evaporation leading to a reduce water volume during dry season (Victus Bobonkey Samlafo 2022). Recently, a study was conducted in rural watersheds of Western Nepal to evaluate the physicochemical properties of spring water sources used by local communities for drinking and domestic purposes during dry and wet seasons. Similar with our findings, higher phosphate concentrations were observed during the dry season and higher dissolved oxygen concentrations were observed during the wet season (Gurung, 2019).

Higher levels of electric conductivity were observed at Hemja and Patneri (291 µS/cm and 293 µS/cm, respectively) during dry season due to the higher concentration of the dissolved solutes resulting from small volume of water. A study conducted by Victus et. al. observed a similar finding with EC ranged between 162.0 µS/cm 180.2 µS/cm during dry season and 61.3 µS/cm 163.6 µS/cm during wet season (Victus Bobonkey Samlafo 2022).

Figure 5 shows the variation in the water quality index of the Seti River at Hemja and Patneri during dry and wet seasons. The observed index value indicates a higher level of pollution in the Seti River during the wet season compared to the dry season. Like this study, Zhao et. al. (Zhao et al., 2018) observed the water quality in the Mun River basin, Thailand was better during the dry season. The WQI index, corresponding classifications and their suitable applications of water samples are presented in Table 2.

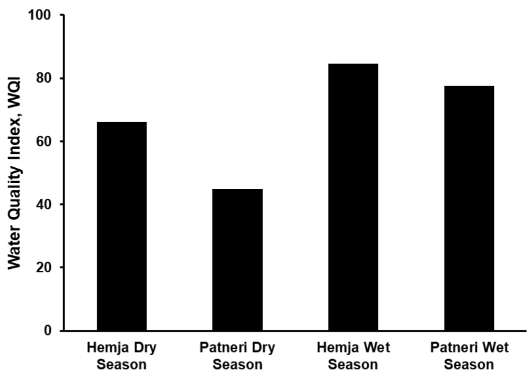


Figure 5: Variation of water quality index at Hemja and Patneri during dry and wet season.

Table 2: Water quality index classification, status and potential applications.

WQI Range	Water Quality Status (WQS)	Potential Applications
0 – 25	Excellent	Suitable for drinking, agriculture and industrial purposes
26 – 50	Good	Safe for human consumption, agriculture and industry
51 – 75	Moderate	Applicable for agricultural and industrial usage
76 – 100	Poor	Agricultural use
>100	Unsuitable for direct consumption	Requires appropriate treatment before any application

5 Conclusion

Various physiochemical parameters were analyzed to evaluate the pollution status of Seti River. Overall, total suspended solids, total hardness as $CaCO_3$ and dissolved oxygen did not meet the acceptable standards during wet seasons. The WQI value suggested significant degradation of water quality classifying them as unsuitable for drinking purposes. This finding highlights the urgent necessity for immediate intervention to mitigate and manage pollution levels, mainly during the wet season. These interventions may include the effective regulations of industrial and agricultural activities, along with the implementation of strict policies to prevent the release of untreated wastewater into the rivers systems.

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Author's contribution

K. Koirala was involved in conceptualization, literature search, analytical methods, investigation, and writing the manuscript. R. Bhandari was involved in review and editing of manuscript, data curation.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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