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Assessment of the Dhobikhola river water using real-time monitoring system

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Abstract

River water quality inside the Kathmandu Valley is deteriorating day by day due to the mixing of untreated industrial and domestic waste. Till now, a few researchers have characterized the water quality of Dhobikhola using traditional methods, therefore, there is a lack of enough data to identify river water quality thoroughly. With the exponential development of information technology, continuous, fine-scale, and real-time data monitoring is possible using advanced sensor probes with sophisticated data logging systems; it would be the first practice in the case of the Dhobikhola River. In this study, real-time continuous monitoring and collection of large data using sophisticated sensors were performed to determine the river water quality and the sources of pollutants. The spatial variation of water quality parameters indicated that after entering the core city area, most parameters, such as conductivity and turbidity, changed more than four times, and oxidation-reduction potential (ORP) turned into a negative value. The high conductivity and negative ORP values are an indication of a sewer connection. Daily and diurnal variations suggested that the Dhobikhola River is always polluted with a negative ORP value (< -50 mV). All the results suggest that it is enormously important to control the mixing of effluent into the Dhobikhola Rivers to revive the ecology of the aqueous system.

Keywords
Diurnal variation, Oxidation-reduction potential (ORP), Real-time data, Water pollution.

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1 Introduction

Dhobikhola is one of the major and most polluted tributaries of the Bagmati River [1,2]. It originates from the Muhanpokhari at Shivpuri Hill, north of Kathmandu Valley, and is mixed into the Bagmati River at Bhuddha Marg, Buddhanagar. It passes through the densely populated area before it merges into the Bagmati River. It extends about 18.2 km [3] and covers about 31.2 square km [4]. Rapid population growth with unmanaged urbanization generated excessive solid waste and sewage in core city areas inside the Kathmandu Valley [5]. Municipal, hospital, and industrial wastes are dumped directly into the river. In addition, domestic and industrial wastewater are connected directly to the river without any treatment [6,7]. Due to the mixing of effluent and solid waste, the water quality of the

Dhobikhola is severely deteriorating in the present conditions [8–10], which harms the river ecosystem and the health of communities relying on it. Near the source, close to Shivpuri Hill, the water is still clean; it is diverted for daily uses for bathing, irrigation, washing vegetables, utensils, and clothing.

The study [3] reported that the sewage discharge and dumping of solid waste into the Dhobikhola River started from the Kapan area. The Dhobikhola River is severely polluted from the Chabahil area and downstream. A huge volume of wastewater from households and industries is directly connected to the river, and municipal waste is disposed of on the banks. These anthropogenic pollutants cause the degradation of the river's water quality. The study also suggested that the river is ecologically almost dead inside the core city area, causing heavy losses due to waterborne diseases. The physicochemical characterization of river water concluded that the Dhobikhola River water is not potable; the observed dissolved oxygen was about 4.4 ppm, and the conductivity was 450 µS/cm [10]. Similarly, a study concluded that the Dhobikhola River water is black, and the alkalinity was 310 ppm [9]. The observed chlorine demand was as high as 20 ppm, suggesting the high amounts of organic/inorganic and pathogenic contaminants in the river water. The assessment of the Bagmati River and its tributaries suggested that the oxidation reduction potential (ORP) of the Dhobikhola River varies between – 40 to -90 mV, with conductivity between 1,090 to 1108 µS/cm, and ammonia and sulphate concentrations were the highest among the tributaries of the Bagmati River. The chlorine demand was as high as 38.70 ppm in winter [11]. Based on the water quality index (WQI), they concluded that water quality is extremely polluted, hence unfit for domestic use. Although these studies suggested that the Bagmati River and its tributaries are polluted by domestic effluent, there is still a lack of enough studies, especially in the case of Dhobikhola only a few studies are available. The daily deterioration of river water quality highlights the necessity to determine the pinpoint of pollutant sources. So that awareness is created among the people to carry out the treatment of industrial and domestic waste before its disposal into the river water body. To pinpoint the sources of pollutants, traditional water quality monitoring methods are not sufficient because there is a limitation of observation points, and it takes a long time to analyze the data. Since the sources of pollutants are mainly domestic influents, real-time and continuous monitoring will provide the eventual and real-time water quality status. In this study, a detailed assessment i.e., the spatial, diurnal, and daily variations of river water quality of Dhobikhola, was analyzed by logging continuous real-time and fine-scale data using an advanced monitoring system. This is a very new approach to monitor/characterize water quality parameters, which is the first experience, especially in the case of the Dhobikhola River. Since it is not possible to collect data of all water quality parameters in real-time and fine-scale basis, this study considered the ORP, dissolved oxygen (DO), and conductivity are the most useful parameters indicating sewer pollutants.

2 Methodology

Data of water quality parameters were collected from nine different positions along the Dhobikhola River from Shivpuri Hills to the Buddha Marga, Budhanagar, the endpoint before confluence with the Bagmati River (Fig. 1). Data were continuously collected and logged every second from 9 stations. The observation started from the farthest upstream site of the Dhobikhola (Dh-1, 27.763°N, 85.365°E), which is located at the entrance point (Bhadrakali Park, Shivpuri Hill) of the Dhobikhola River. This observational area has a clean environment, is far from the residential area, and is mainly covered by a forest. The second and third observation sites were the Sapridhunga, Kapan (Dh-2, 27.745°N, 85.359°E), and Narrow Bridge, Budhanilkantha (Dh-3, 27.733°N, 85.351°E). The Dh-2 and Dh-3 sites are rural areas and have little influence from newly developed residential areas. The next sampling site was Gopikrishna, Chabahil (Dh-4, 27.722 °N, 85.345 °E), a core city that started from this area. The sampling sites Dh-5 and Dh-6 are highly populated areas i.e., Kalopul (27.712°N, 85.338°E) and Setopul, Maitidevi (27.7°N, 85.332°E) areas. Other observation sites Dh-7, Dh-8 and Dh-9 were the Bijulibazar (27.692°N, 85.329°E), Anamnagar (27.688°N, 85.326°E) and Buddha Marg, Buddhanagar (27.687°N, 85.324°E) areas. The sewer lines are directly connected to the river water in these areas (from Dh-4 to Dh-9) and are considered heavily polluted areas of the Dhobikhola River [5] (NUD). The diurnal variations were determined by collecting data at the Dh-6 on 27 July and 4 August.

Real-time fine-scale water quality data were measured using an Advanced-Multi-Parameter Analyzer (HANNA instruments, Hi-9829) [11]. Physicochemical parameters such as water pressure, turbidity, pH, temperature, oxidation-reduction potential (ORP), dissolved oxygen (DO), conductivity, salinity, total dissolved solids (TDS), and global positioning systems (GPS) were measured and logged on a real-time basis.

Figure 1: Map of Dhobikhola River including observation points. The circle with a dashed line indicates a core city area with heavily contaminated river water.

3 Results and Discussion

3.1 Spatial Variation of Water Quality Parameters

Data was collected from nine different sites along the Dhobikhola River (Fig. 1). The physicochemical characterization of the water suggests the river's water quality. In this study, the physicochemical characteristics of water were determined along the Dhobikhola River using a fixed sensor system. The data was collected from nine fixed stations. The sampling sites were chosen to find the source of pollutants, which varied water quality parameters along the space domain of the Dhobikhola River. Data collection started from Shivpuri and ended at the Budhanagar site on the same day. More than 500 data sets were collected from each station. Data collection was started at 11:30 and ended at 13:30 on 19 September 2024. The observed water quality parameters were shown with a heat map (Fig. 2), and data were presented in Table 1. The river water temperature varied from 21.95±0.3 to 27.40±0.06 °C. As expected, the river water temperature was low initially upstream and increased slowly downstream due to time variation, i.e., air temperature (Fig. 2a). The pressure of the water enhances slowly downstream (Fig. 2b). The observed turbidity was as low as 42.87 ±16.55 FNU at the Dh-1 and higher than 200 FNU at other observation sites except Dh-3 and Dh-4 (Table 1, Fig. 2c). The increase of turbidity downstream may be due to the mixing of soil or effluent in the river water [12]. The hydrogen ion concentration in water is characterized by pH value. Water with a pH less than 6.5 could be soft while water above 8.5 could be hard and corrosive [13, 14]. pH of river water was comparatively high (7.62±02) upstream and decreased slowly to7.26±0.01near the end of the Dhobikhola River (Fig. 2d). Observed pH falls within the WHO standard of natural water (6.5 to 8.5) [14]. The slightly alkaline pH of river water may be due to the presence of weak bases from soil and sand, ammonical compounds from domestic effluent and agricultural surplus [15] and/or microbial decomposition of organic matter [16]. Conductivity is associated to the conductive ions present in the water. The low conductivity (123.4 ±6.39 µS/cm) was observed at Dh-1, the conductivity was more than two times at Dh-2 (234.28 ±2.84 µS/cm). It was increased almost continuously downstream (Fig. 2e). The conductivity of river water at the last observation point (618.93±2.03) was more than five times higher than at Dh-1 (123.4 ±6.39 µS). As shown in the table, total dissolved solids (TDS) were low, 61.64 ± 3.2 ppm at Dh-1 and linearly increased till Dh-3 then drastically at Dh-4, and it was almost fivefold higher at Dh-9, the end of the observation site. Similarly, salinity was 0.06±0.003psu at Dh-1 continuously 0.30±0.001psu downstream. Unusual enhancement of conductivity, salinity and TDS downstream of the river suggests the inflow of municipal and industrial discharge [17] because industrial and domestic wastewater consists of a high concentration of salts [18, 19].

Table 1: Water quality parameters at nine different sites along the Dhobikhola River

Parameter	Dh-1	Dh-2	Dh-3	Dh-4	Dh-5	Dh-6	Dh-7	Dh-8	Dh-9
GPS Latitude	27.76289	27.74805	27.73354	27.72201	27.71214	27.69985	27.6922	27.6878	27.68722
GPS Longitude	85.36459	85.35872	85.35104	85.34539	85.33758	85.33245	85.32878	85.32646	85.32463
Pressure [mmHg]	652.55±0.09	655.08±0.63	656.92±0.13	657.44±0.12	658.26±0.60	659.75±0.35	660.05±0.92	661.09±0.42	658.96±0.22
Temperature [°C]	21.95±0.3	25.72±0.06	26.34±0.06	26.75±0.05	26.34±0.05	26.7±0.02	26.94±0.03	27.02±0.01	27.40±0.06
Turbidity [FNU]	42.67±16.55	230.52±13.91	73.25±11.03	146.79±21.64	210.06±20.28	263.66±147.47	206.70±18.51	218.52±16.46	200.03±15.30
pH	7.62±0.02	7.42±0.01	7.33±0.02	7.25±0.01	7.22±0.02	7.26±0.01	7.26±0.01	7.29±0.01	7.30±0.02
ORP [mV]	82.56±1.41	79.60±2.69	105.69±15.49	-44.63±24.23	-94.94±18.02	-80.72±20.33	-93.22±13.33	-70.89±21.48	-45.68±19.74
EC [µS/cm]	123.14±6.39	234.28±2.84	289.29±0.75	474.67±0.66	587.61±1.19	563.77±31.71	629.56±0.83	630.85±0.76	618.93±2.03
TDS [ppm]	61.64±3.2	117.13±1.44	144.63±0.48	237.33±0.49	293.79±0.52	281.98±15.89	314.74±0.44	315.53±0.52	309.50±1.11
Salinity [psu]	0.06±0.003	0.11±0.001	0.14±0.0003	0.23±0.0003	0.28±0.001	0.27±0.02	0.30±0.0004	0.30±0.001	0.30±0.001
DO [ppm]	2.95±0.09	3.07±0.04	3.08±0.03	3.13±0.04	3.04±0.04	3.14±0.03	3.21±0.02	3.19±0.01	3.13±0.05

Another vital parameter of the water quality is the dissolved oxygen (DO). The variation of concentration of DO was not pronounced in the river water. It was around 3 ppm in all observation sites. The oxidation-reduction potential (ORP) is most prominently used in wastewater treatment to measure the water disinfection potential [20, 21]. The reducing agent present in the water decreases the ORP value, and an oxidizing agent increases the ORP value, hence, it reveals the biological reaction occurring in the water. The observed ORP of river water was positive and higher than 50 mV upstream (82.56±1.41) and that was negative and it ranged from (-)44.63±24.23 to (-)94.94±18.02 downstream. The studies [20, 21] considered that 50 to 250 mV ORP is suitable for the degradation of organic compounds and the nitrification process. The ORP value between +50 and -50 mV is useful for denitrification, and between -50 to -250 mV is useful for the formation of sulfide and release of biological phosphorus. The positive ORP value reveals the clean and unpolluted water upstream, and the negative value (< -50 mV) downstream suggests that the river water is extremely polluted with reducing substances from wastewater; hence, dissolved oxygen is not enough to decompose organic compounds, instead producing sulfide and biological phosphorus, generating a stinky smell. The negative ORP value suggested that there is a lack of enough oxygen to decompose organic pollutants and dead tissue, which increases the contaminants, and the river water becomes toxic to aquatic animals, hence to the public. In addition, a low ORP value is suitable to generate a stinky smell, which is responsible for an unhealthy environment around it.

3.2 Diurnal Variation of Water Quality Parameters

Fine-scale and real-time data of Dhobikhola River water quality parameters were collected in July and August 2024 in the monsoon period. Diurnal variations of water quality parameters were plotted in Fig. 4 and Fig. 5. The diurnal variations showed that the temperatures of the river water varied with time in the observation sites. The maximum temperature was observed at about 3 pm on both observation days (Fig. 3a). The temperature varied from 24 to 28.58 °C. The diurnal variation of pH was not pronounced, though it ranged from 7.43 to 7.56 (Fig. 3b). Conductivity was slightly increased initially and reached a maximum at noon and decreased slowly with time. The highest recorded conductivity was about 488 µS/cm and the lowest value was about 422 µS/cm on July 27 and it was 502 and 468 µS/cm, respectively, on August 4 (Fig. 3c). Dissolved oxygen (DO) in water depends on atmospheric oxygen and photosynthesis. The DO is consumed by biochemical and chemical phenomena [22,23]. The observed dissolved oxygen was less than 2 ppm and remained almost constant during the observation time. Fig. 4a shows that the concentration of DO was not affected by time and temperature during observation. A very low concentration of DO indicates that it is almost impossible to survive aquatic animals on it. The ORP value was negative for the whole day on July 27 and tends to the negative after 12:30 on August. The diurnal variation of ORP value was distinctly different on Aug 4 than that on July 27(Fig. 4b). The variation of ORP was negatively related to water pressure suggesting the loading of sewer which decreased the ORP value (Fig. 4c).

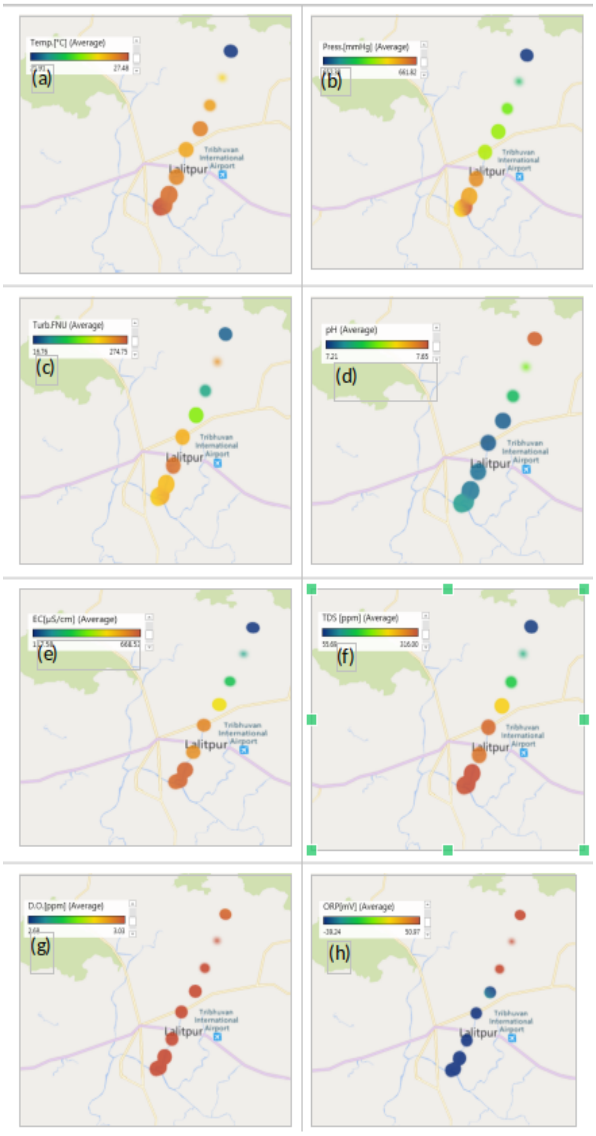

Figure 2: Spatial variation of water quality parameters of Dhobikhola (a) Temperature (oC) (b) Water pressure (mmHg) (c) Turbidity (FNU) (d) pH (e) Conductivity (µS/cm) (f) TDS (ppm), (g) DO (ppm), and ORP (mV).

3.3 Daily Variation of Water Quality Parameters

Daily variations of water quality parameters of Dhobikhola River were observed pre-monsoon (June), monsoon (July-August), and post-monsoon (September). The observed temperature, water pressure, pH, and turbidity were plotted in Fig. 5. The water temperature ranged from 26 to 28 °C during the pre-monsoon period and reduced the temperature slightly, which ranged from 22 to 24 °C in the post-monsoon period (Fig. 5a). The enhancement of water pressure was distinctly observed in the monsoon and post-monsoon periods (Fig. 5b). The pH was comparatively higher in the pre-monsoon than in the post-monsoon period (Fig. 5d). The decrease in pH after rainfall may be due to the dilution of alkaline pollutants in the water. A similar effect was also observed in the case of the turbidity of water (Fig. 5c). A distinct daily variation was observed in the conductivity (Fig. 6a). It was higher than 600 µS/cm in the pre-monsoon period and reduced to less than 500 µS/cm in the post-monsoon. The conductivity was reduced to nearly half by the rain. The total dissolved solids were a maximum on June 21 in the pre-monsoon period and a minimum on Sep 16 in the post-monsoon period (Fig. 6b). The dissolved oxygen was as low as 2 mg/L and remained almost constant in all observation days (Fig. 6c). The ORP value was always negative in the Dhobikhola River, though a slight increase was observed during the post-monsoon period (Fig. 6d). The dissolved oxygen and ORP values indicated that the water quality of Dhobikhola River was always heavily polluted. The rainfall slightly reduced the pollutants; however unable to enhance the water quality. The very low ORP indicated that the water consists of organic pollutants that consume dissolved oxygen excessively. The negative ORP value (<-50 mV) suggested that there were excessive amounts of organic contaminants from the sewer, which excessively reduced dissolved oxygen. The inflow of domestic effluent loaded the pollutants continuously, hence unable to dilute it by heavy rainfall even in the monsoon season. This is the reason why the dissolved oxygen remains low in all seasons.

3.4 Correlation Between Water Quality Parameters

Correlation indicates the extent to which two variables vary together. A positive correlation shows the level to which those variables increase or decrease, whereas a negative correlation shows the level to which one variable increases as the other decreases. The correlation between different water quality parameters on different observation days was plotted in Fig. 7. There are both negative and positive correlations between the two variables, however, the coefficient of determination (R^2) was always low. The conductivity and pH show a negative correlation with the water pressure (Fig. 7a and 7b). Fig. 7c and Fig. 7e show the positive correlation between conductivity and turbidity and between conductivity and pH, respectively. Fig. 7d and Fig. 7f show the negative correlation between ORP and turbidity and between ORP and conductivity, respectively. The correlation revealed the positive impact of turbidity on conductivity i.e, pollutants increased turbidity and conductivity and hence decreased ORP values. The maximum value ($R^2 = 0.4742$) was obtained for the relation between ORP and conductivity. The negative relation between these two parameters suggested that domestic effluent increases conductive organic pollutants and/or microorganisms in addition to conductive ions in the river water. The contaminants use up dissolved oxygen excessively for their decomposition by decreasing the ORP value. It is considered that the organic pollutants from domestic effluents increased excessive contaminants in the Dhobikhola, which reduces ORP excessively by using dissolved oxygen. Due to the presence of excessive contaminants rain fall increased the water press however unable to dilute the contaminants noticeably in the Dhobikhola River.

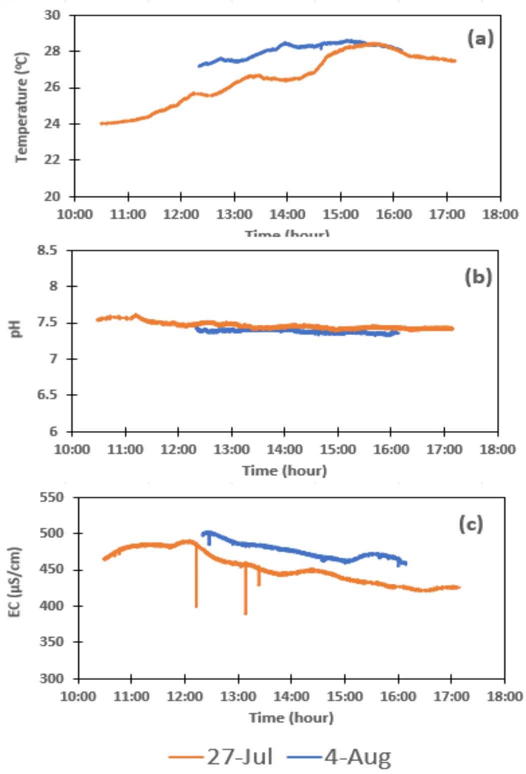

Figure 3: Diurnal variation of (a) Temperature, (b) pH, and (c) Conductivity (EC) in the Dhobikhola River.

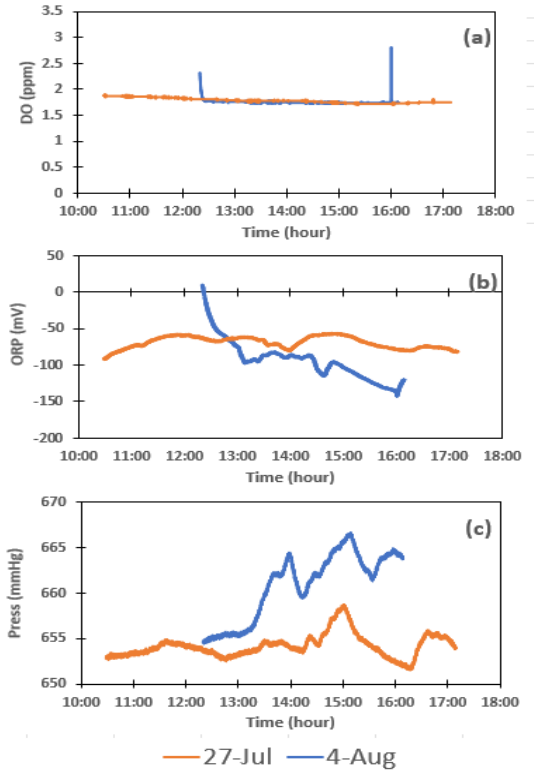

Figure 4: Diurnal variation of (a) DO, (b) ORP, and (c) Water pressure in the Dhobikhola River.

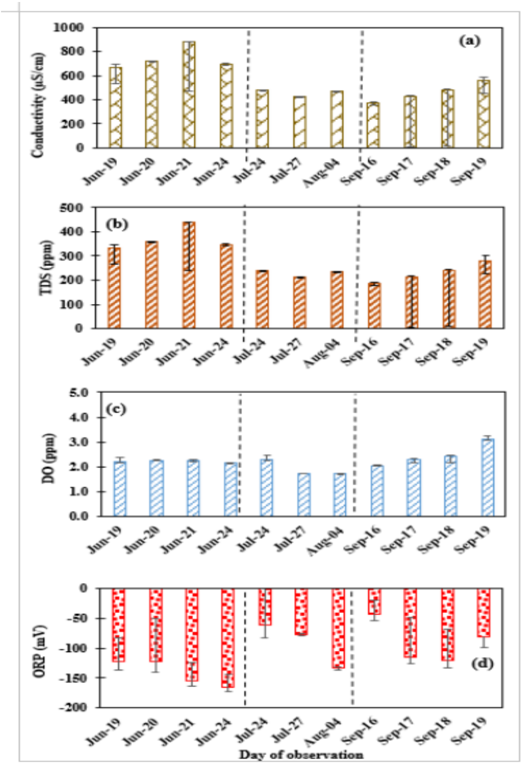

Figure 6: Daily variation of (a) Conductivity, (b) DO, and (c) ORP during the monsoon season.

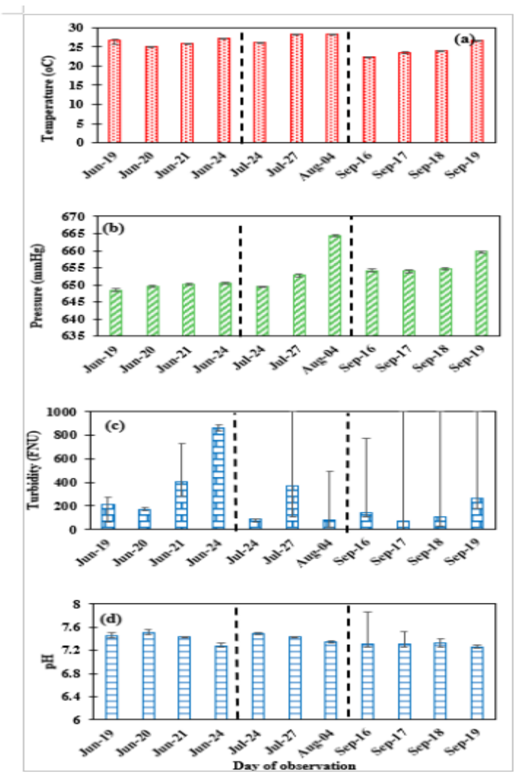

Figure 5: Daily variation of (a) Temperature, (b) Pressure, (c) Turbidity, and (c) pH during the monsoon season.

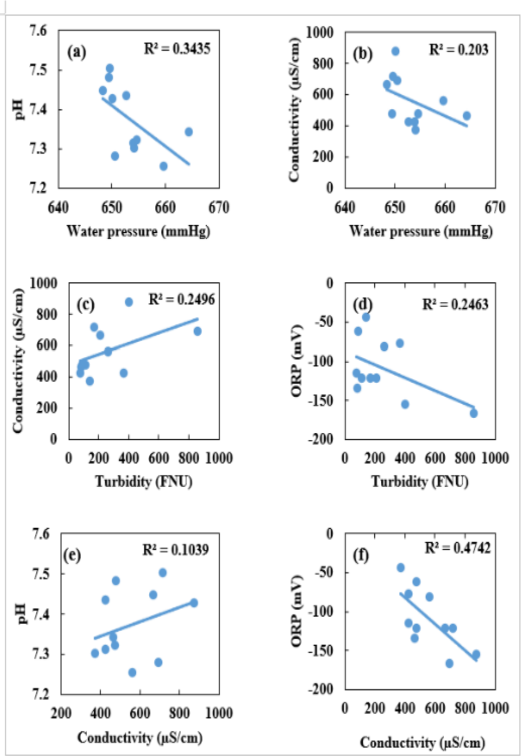

Figure 7: Correlation between different water quality parameters observed on different days in the monsoon season.

4 Conclusion

This study monitored and analyzed fine-scale real-time water quality along the Dhobikhola River using advanced sensor systems. The diurnal, spatial and daily variations of parameters such as temperature, pH, salinity, conductivity, total dissolved salt (TDS), dissolved oxygen (DO), and turbidity were recorded. The analytical results distinctly showed that the water quality of the Dhobikhola River upstream (Dh-1, Dh-3) and downstream (Dh-4 to Dh-9) was radically different. the conductivity was less than 200 µS/cm upstream but was nearly 250 µS/cm at the beginning of downstream and linearly increased to 630 µS/cm at the end of the observation site. Further, oxygen reduction potential (ORP) was positive upstream and negative at the downstream site. The low and negative value of ORP is associated with contaminated water containing large amounts of reducing pollutants. The immense change in water quality parameters upstream and downstream on the same day suggests the influence of locally generated pollutants such as domestic, agricultural, and industrial effluents from the urban area. The daily variation of water quality parameters showed that river water is extremely polluted downstream, not only on a single day but almost every day. The monsoon rain is also unable to reduce pollutants to an acceptable level. The pH and conductivity were increased, but ORP was decreased during the day. The correlation between the water quality parameters indicated that the pollutants increased the turbidity and conductive substances in the river water and reduced ORP value to a highly unacceptable level downstream.

From the analytical results, it is concluded that the solid wastes and domestic and industrial sewers loaded organic pollutants and reduced molecular oxygen excessively so that living organisms could not survive in it. In the absence of molecular oxygen, the microorganisms decompose pollutants by generating volatile matter, which is responsible for the hazardous fouling smell along the bank of the river.

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