Assessment of various physico-chemical water quality parameters: a case study on Bhairab River, Bangladesh

Biplob Kumar Biswas*, Kazi Al-Imran and Abdullahil Mubdee

Department of Chemical Engineering,
Jashore University of Science and Technology,
Jashore, 7408, Bangladesh
Email: bk.biswas@just.edu.bd
Email: imranche101@gmail.com
Email: noorche2009@gmail.com
*Corresponding author

Abstract: This study was conducted to assess various physico-chemical parameters of water quality of Bhairab River in the Noapara Region, Jashore, Bangladesh and to comprehend the present pollution scenario of that river in the studied region. Samples were collected from three different points during the study period (October 2015 to August 2016) and analysed for various water quality parameters. The mean values of temperature, pH, salinity, TDS, EC, BOD, COD, DO and turbidity were found to be 29°C, 8.4, 395.8 mg/l, 570 mg/l, 776.3 μS/cm, 2.14 mg/l, 12.44 mg/l, 4.86 mg/l and 554.4 mg/l, respectively. Water quality index was determined and found to be much higher than the suitability limit of water for drinking. Thus, the study showed that the water quality was not suitable for drinking or cooking purposes rather the river water could be used for irrigation, navigation and recreational purposes.

Keywords: physico-chemical parameters; Bhairab River; pollution; Noapara; Bangladesh.

Reference to this paper should be made as follows: Biswas, B.K., Al-Imran, K. and Mubdee, A. (2021) 'Assessment of various physico-chemical water quality parameters: a case study on Bhairab River, Bangladesh', *Interdisciplinary Environmental Review*, Vol. 21, No. 2, pp.87–100.

Biographical notes: Biplob Kumar Biswas is a Professor of the Department of Chemical Engineering, Jashore University of Science and Technology, Bangladesh.

Kazi Al-Imran was a student of the Department of Chemical Engineering, Jashore University of Science and Technology, Bangladesh while conducting the research.

Abdullahil Mubdee was a student of the Department of Chemical Engineering, Jashore University of Science and Technology, Bangladesh while conducting the research.

1 Introduction

Water is the most vital element of environment and very essential substance for the nature and ecosystem of the world. Lives of many aquatic creatures as well as numerous human activities depend on quality water resources (Ezugwu et al., 2019). Quality water is very much essential for human health and life too (Ezugwu et al., 2019; Mgbenu and Egbueri, 2019). Accessibility to safe drinking water to all is one of the sustainable development goals (SDGs) for governments of many countries of the world. Ensuring supply or accessibility to quality water for people is known to be very much linked with well-being and favourable living conditions of human (Babatimehin et al., 2020; Uddin et al., 2020). Water, both groundwater and surface water, has a number of unique chemical and physical properties that make it indispensable to human life (Biswas and Mandal, 2014). Moreover, there are several factors that control chemistry of aquifer, groundwater and surface water (Etikala et al., 2019; de-Oliveira and Galvão, 2019). Rainfall as well as trans-boundary river flows are the main sources of surface water in Bangladesh (Hoque et al., 2012). As Bangladesh is a land of nearly 700 rivers including tributaries flowing all over the country, the economic development of the country highly depends on river water (Chowdhury, 2001). It is obvious that most of the industries are established along the banks of the rivers. This has happened due to availability of water from the river as well as easy disposal of wastes (Lokahnde et al., 2011). These wastes often contain a vast range of hazardous contaminants, which include but not limited to heavy metals, dyestuffs, hydrocarbons, alkalis and acids. All such wastes heavily affect (in terms of water pollution) both flowing water as well as stagnant water (Malik et al., 2013).

It is evident that surface water of a country plays a major role in overall economic development of a country. But due to unplanned disposal of domestic and industrial wastes, surface water is getting polluted day by day in many countries. It is needless to mention that the surface water of Bangladesh is poorly managed natural resource and not protected from untreated industrial effluents and municipal wastewater, which are polluting surface water at a great extent. Apart from that, unplanned disposal of solid waste, accidental oil spillage, overuse of chemical fertilisers and pesticides, etc. are potential threat to existence of human being (Rahman et al., 2008). The major concerns of water quality relates not only to the water itself, but also to the danger of toxic substances diffusion into other ecosystems. Water quality parameters can be classified into three major categories such as, physical, chemical and biological (Mustapha et al., 2013). Any abnormalities such as increase or decrease of extent of those parameters may affect the aquatic animals tremendously, which in turn affect the entire civilisation of a region.

Parameters of surface water may vary significantly due to seasonal variation of river flow, various industrial operations round the year and utilisation of agrochemicals (Khan, 2010). The Bhairab is a major contributing river of the south-western part of Bangladesh flowing over several districts. It has been originated in India and enters into Bangladesh at Meherpur district. On its tortuous course, the Bhirab has come across many towns and municipalities of Meherpur, Chuadanga, Jhenidah, Jashore, Narail and Khulna districts. The river is approximately 242 km long (Khan et al., 2019). Although the Bhairab is not the largest river of Bangladesh, it has an immense importance for trade, commerce, and irrigation to the people of Jashore, Noapara and Khulna. Many kinds of businesses such as jute industry, textiles, tannery, fibre industry, cement industries, oil refineries, etc.

have been flourished either on the bank of the river or close to the river. Different types of garbage and untreated effluent are directly thrown into the river water that leads to severe pollution of the river water. Since a very few study is reported on Bhairab River, it is necessary to investigate the water quality of this river. Uddin (2015) reported physico-chemical properties of Bhairab River water covering mostly the river part in Khulna City, Bangladesh. Although Khan et al. (2019) monitored seasonal variation of several heavy metals only in the Bhairab River water in Noapara industrial area, but did not report other physico-chemical properties. Thus, the objective of this study was to investigate the essential physico-chemical water quality parameters of the Bhairab River water in Noapara of Abhaynagar Upazilla of Jashore District, Bangladesh, and to make a comparison with Bangladesh standards of river water quality suitable for the fishes and living organism in water.

2 Materials and methods

2.1 Study area

Noapara, a small industrial and business centre of Jashore District, was selected as the study area. It is situated at the bank of river Bhairab. The total area of the Noapara municipality is 25.11 km^2 (Khan et al., 2019). The elevation of Noapara is 9 m from the sea level (Website of Elevation Map, 2020). It is lying within latitudes 23.058758° N to 89.386231° E and longitudes 23.009595° N to 89.420928° E. In the last 20 years, the average annual temperature and precipitation of Jashore is 26.1°C and 162 cm, respectively (Website of Average Weather, 2020). Three different locations were selected as sampling sites in Noapara such as:

1. Shankarpasa Ferry Ghat as upstream study point
2. Shankarpasa Kheya Ghat as middle stream point where the river receives wastes from market place as well as from tannery industry
3. Taltala Kheya Ghat as downstream study point where the river leaves the study area.

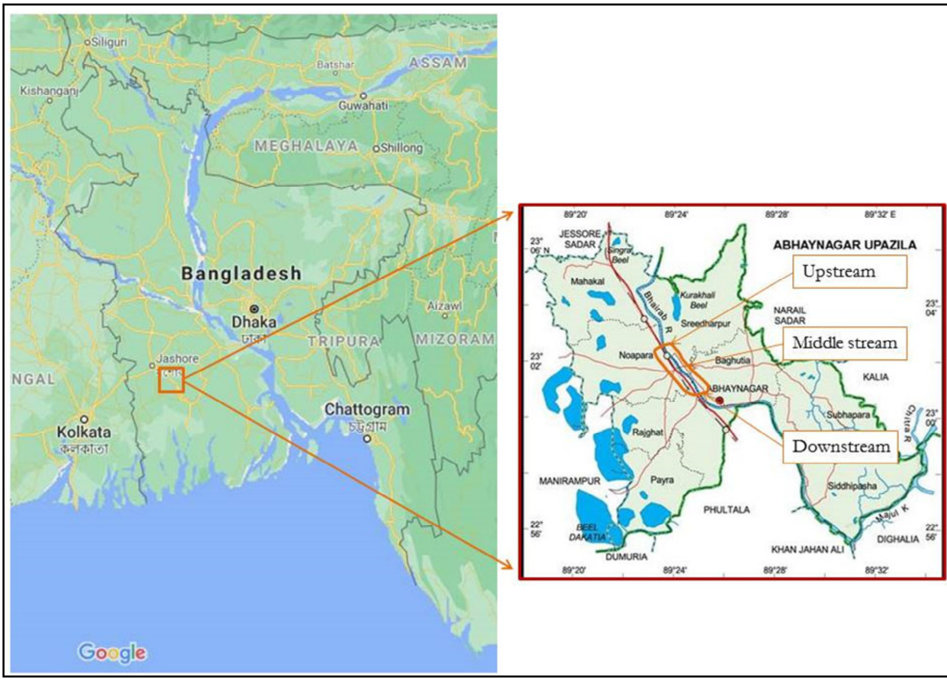
These three sampling sites cover the whole Noapara municipality. The sampling points were selected on the basis of point sources of pollution. Thus, the water quality parameters of those sites would give a clear idea of water pollution of Bhairab River in the study area. The study area is shown in Figure 1.

2.2 Sample collection

River water samples were collected from the study area once in a month. The study was conducted from October 2015 to August 2016. Sample bottles (500 ml plastic bottles) were first washed with dilute nitric acid and then rinsed repeatedly with distilled water. While collecting samples from the river, the bottles were again rinsed two or three times with the water that was to be stored (Khan and Khan, 2019). The bottles were filled with water in such a way that there was no air space inside. This was done to avoid any reaction with air. However, chemicals used in this study were of analytical grade. Water samples of approximately 500 ml were collected from the middle of the river in preselected sample bottles from the above mentioned study areas for laboratory analysis.

Water samples were collected from about 0.50 m below the river water surface. However, before collecting samples, the sample bottles were rinsed three times with the river water so that the moiety of the bottled water remains like river water (Tareq et al., 2013). After collecting the samples, the bottles were screwed and labelled. The samples were carried in a dry bag and transported to the laboratory for further analysis.

Figure 1 Location of the study area (see online version for colours)



Source: Google Maps (2020)

2.3 Sample analysis

Various parameters such as temperature, pH, salinity, electrical conductivity (EC), total dissolved solid (TDS), biological oxygen demand (BOD), chemical oxygen demand (COD), turbidity, chromium and dissolved oxygen (DO) were analysed in the present study. Samples were taken twice a month from three sampling sites. The arithmetic mean of data was used as average value for each parameter (except pH). For calculating average value of pH, a logarithmic mean was used. However, different methods were used for the determination of various physico-chemical properties of water samples, which are depicted in Table 1 (Sinha and Biswas, 2011). Besides, colour, door and transparency were observed by visual and physiological sense.

Table 1 Determination methods of physico-chemical parameters

Parameters (unit)	*Used methods and instrument*
Temperature (°C)	Thermometer
pH	Portable pH meter (EZODO 6011 pH tester)
Salinity (mg/l)	Digital multimeter (DANOPLUS 6-in-one water quality tester M0199720)
Turbidity (NTU)	Attenuated radiation method (HACH portable spectrophotometer)
Electrical conductivity (µS/cm)	Digital multimeter (DANOPLUS 6-in-1 water quality tester M0199720)
Total dissolved solid (mg/l)	Digital multimeter (DANOPLUS 6-in-1 water quality tester M0199720)
Biological oxygen demand (mg/l)	Titrimetric method
Chemical oxygen demand (mg/l)	Permanganate titration method
Chromium (mg/l)	Atomic Absorption Spectroscopy (AA-7000, Shimadzu, Japan)
Dissolved oxygen (mg/l)	Winker titration method

3 Results and discussion

3.1 Colour and odour

Colour and odour of the sample water were investigated visually. Over the study period, the colour was found to be more or less clear and no greenish blue colour was observed. This is a good indication for aquatic creatures such as fishes (Das, 1997; Gupta, 2001). This is due to the phytoplankton enrichment of water. Bad organic odour was experienced in the month of August and September due to the rotten jute in the river water.

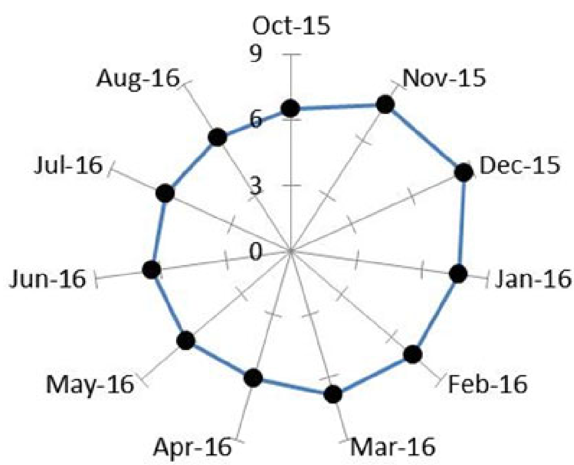
3.2 Temperature

Table 2 shows the temperature of the Bhairab River at different seasons. Although the temperature of river water was reported to be 20°C–30°C (ECR, 1997), in this study, the water temperature was found to be in a greater range (such as from 21°C to 34°C). The average temperature was found to be 29°C while the highest and the lowest temperatures were recorded as 34°C and 21°C in June 2016 and January 2016, respectively. The fluctuation of temperature of river water usually depends on the season, geographic location of the site, sampling time and temperature of effluents entering into the river (Ahipathi and Puttaiah, 2006). However, the highest temperature of the river water was thought to happen due to the turbidity of the water. Because of turbidity, the tiny particles absorb the sunlight as a result the average temperature increased.

Table 2 Average values of different physico-chemical parameters of the water of Bhairab River

Month	*T (°C)*	*pH*	*TDS (mg/l)*	*EC (µs/cm)*	*Salinity (mg/l)*	*Turbidity (NTU)*	*Chromium (mg/l)*
Oct. 2015	31.5	6.5	320.2	484.5	242.7	NM	NM
Nov. 2015	26.0	8.1	400.0	595.3	296.0	NM	NM
Dec. 2015	23.0	8.4	557.3	835.0	418.3	NM	NM
Jan. 2016	21.0	7.2	685.7	1025.0	511.3	NM	NM
Feb. 2016	24.0	7.3	799.0	1181.0	595.3	NM	NM
Mar. 2016	30.5	6.9	838.3	826.3	417.5	NM	NM
Apr. 2016	32.5	6.2	986.7	1074.5	538.3	785.3	< 0.05
May 2016	33.0	6.3	673.0	1005.0	502.0	238.7	< 0.05
Jun. 2016	34.0	6.6	617.3	925.3	476.3	649.7	< 0.05
Jul. 2016	31.0	6.1	192.7	285.0	142.7	526.3	< 0.05
Aug. 2016	32.0	6.1	209.0	302.0	160.7	572.0	< 0.05

Figure 2 Graphical presentation of pH of Bhairab River water at the sampling site from October 2015 to August 2016 (see online version for colours)



3.3 pH

Since most of the aquatic organisms are got used to an average pH, it is thought to be an important chemical parameter in river water. The pH is affected by both inorganic and organic solutes of the water. The measured values of pH are depicted in Table 2 where it is evident that the pH changes from 6.06 to 8.60. The average pH round the year was calculated to be 6.91. The pH ranging from 6 to 9 is reported to be suitable for the existence of the most living organisms (Saifullah et al., 2012). It is obvious from Figure 2 that the value of pH round the year falls within the permissible range (between 6 and 9). It resembles with the findings for Shitalakhya River in Narayanganj, Bangladesh (DoE, 2016). However, the increase in pH in several months (e.g., November 2015, December 2015 and January 2016) might be attributed to the effluent discharged by various industries located in Noapara, which include but not limited to leather industry, fertiliser industry, cement industry and leachate from pile of coal as well limestone at the river bank.

3.4 Total dissolved solid

TDS generally indicates the presence of some minerals like phosphate, ammonia, nitrite, nitrate, sulphates, alkalis, acids, and some metallic ions comprising both colloidal and dissolved solids in water (Rahman and Bakri, 2010). According to Bangladesh standards of water quality parameter, the maximum allowable limit of TDS is 1,000 mg/l (DoE, 1997; Website of DPHE, 2020; WHO, 2004). The TDS values of different study locations are shown in Table 2. In this study, the TDS values of the Bhairab River water ranged from 192.7 mg/l to 986.7 mg/l. The highest value was observed 1,035 mg/l in April 2016 at downstream area. This higher value of TDS is mainly due to the presence of silt and clay particles in the river water. The lowest TDS value was observed 190 mg/l in July 2016 at upstream area. The average value of TDS was 606.3 mg/l. The average value of TDS shows that it falls within the permissible limit of Bangladesh standards (DoE, 1997; Website of DPHE, 2020).

3.5 Electrical conductivity

EC is a measure of how well water can pass an electrical current. Conductance depends upon the number of ions present in a water body. In the dry season, due to decreases of net water volume the number of total ions increases. And thus, the conductivity of river water increases. On the other hand, during monsoon, the water volume in river increases and thus the EC decreases. The standard value of EC of water is 300 µS/cm (Hoque et al., 2012). However, the spatial and temporal variations of values of EC are presented in Figure 3 while the mean of EC (for different sampling points) with respect to time are shown in Table 2. From Figure 3, it is obvious that the mean values of EC of the Bhairab River ranged from 287.5 µS/cm to 1,181 µS/cm. The highest EC value was found to be 1,270 µS/cm in February 2016 at downstream area and the lowest value was 280 µS/cm in July 2016 at upstream study area. The average value of EC (776.3 µS/cm) exceeded the standard value indicating the pollution of river water.

3.6 Salinity

Salinity is a general term, which means the saltiness or the dissolved salt content of water body. Such salt may be sodium chloride (NaCl), magnesium sulphate ($MgSO_4$), magnesium bicarbonate ($(MgHCO_3)_2$), calcium sulphate ($CaSO_4$), calcium bicarbonate ($Ca(HCO_3)_2$), etc. Salinity is an important parameter that influences the ecological scenario of a water body such as river, lake, etc. It could be a key limiting factor for crop yield too in poorly drained soils if saline water is used for irrigation purposes (Roy et al., 2014). The spatiotemporal variations of salinity are depicted in Figure 4. At the same time, the average value of salinity at different study locations is shown in Table 2. In this study, the average salinity of the Bhairab River ranges from 142.7 mg/l to 594.3 mg/l at various time of the study period. The average salinity obtained was 392 mg/l. The highest salinity was found to be 645 mg/l in February 2016 at downstream point while the lowest value was found to be 141 mg/l in July 2016 at upstream point. Such result might be attributed to the fact that the month of February is the dry season and there is no rainfall at that time around. As a result, various effluents from the industry may increase the concentration of different salts and the salinity increases. On the other hand, during the rainy season the salts get diluted and thus the salinity becomes low.

Figure 3 Spatiotemporal variations (vertical bars) of EC along with their mean values (black dotted line) (see online version for colours)

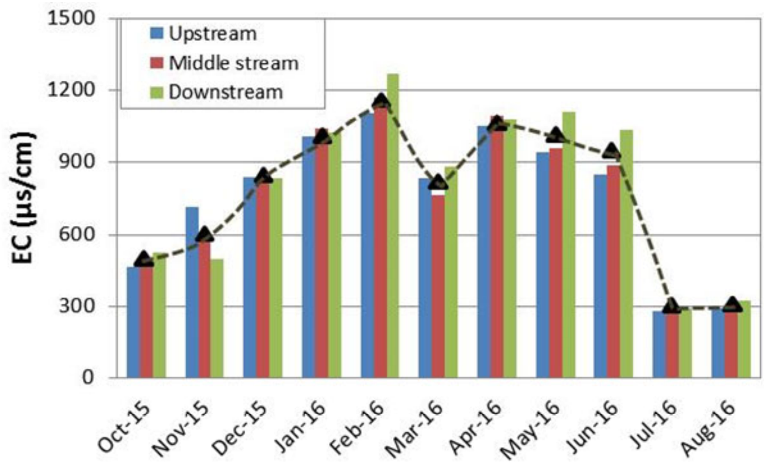
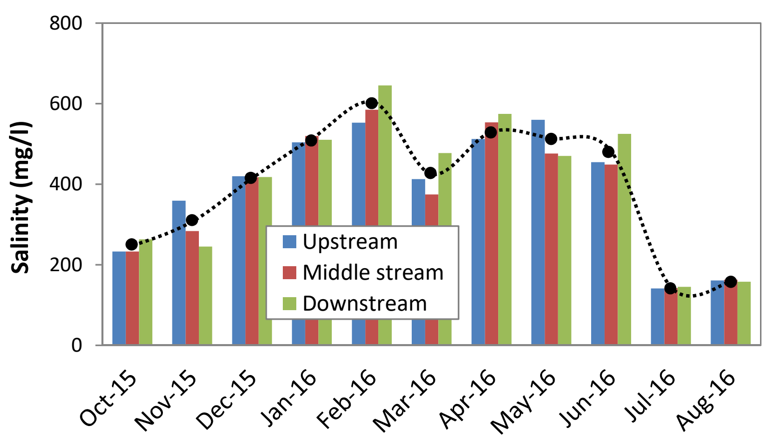


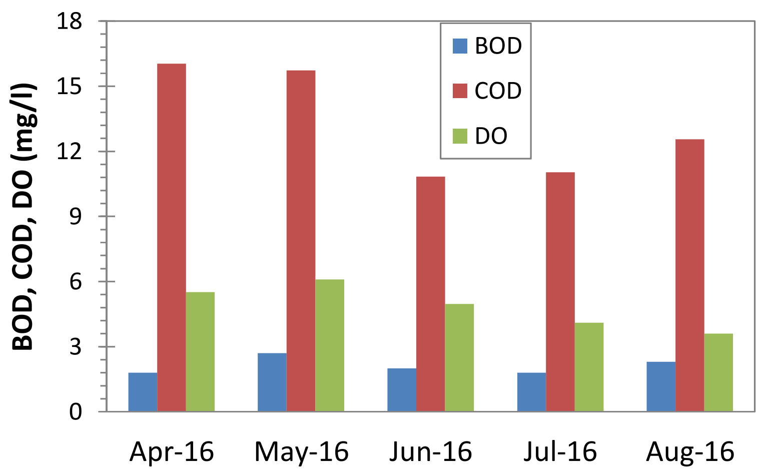
Figure 4 Spatiotemporal variations (vertical bars) of salinity along with their mean values (black dotted line) (see online version for colours)



3.7 *Biological oxygen demand*

BOD is defined as the amount of oxygen required by bacteria and other microorganisms in the decomposition processes of organic matter present in water. Typically, the test for BOD is conducted over a five-day period (Patil et al., 2012). The pH, types of microorganisms, presence of toxins, some mineral matters and nitrification process are the dominant factors for the BOD test (Hasan et al., 2009). The permissible limit of BOD for drinking water is reported to be 0.2 mg/l, while for recreation, fish and irrigation the permissible limit is 3 mg/l, 6 mg/l and 10 mg/l, respectively (Tareq et al., 2013). The higher the BOD level, the lower the DO level. The BOD values at different study times are shown in Figure 5. In the present study, the BOD values of water of Bhairab River ranged from 1.8 mg/l to 2.7 mg/l. The average BOD value was 2.21 mg/l while the highest value of BOD was found 2.7 mg/l in May 2016 and the lowest value was 1.8 mg/l in April and July 2016. This investigation shows that the average BOD values of the water is suitable for fishes and irrigation.

Figure 5 BOD, COD and DO of Bhairab River water at Noapara, Jashore (see online version for colours)



3.8 *Chemical oxygen demand*

COD is an important parameter for measurement of quality of water and/or wastewater. It is used as an indicative measure of the oxygen equivalent in a sample that can be consumed by reactions. Relatively high COD value may cause oxygen depletion. The standard value for COD is 4 mg/l (DoE, 1997). The COD values of different study times are shown in Figure 5. In this study, the COD values of the Bhairab River ranged from 10.84 mg/l to 16.04 mg/l. The average value of COD was 13.2 mg/l. The highest value of COD was observed to be 16.04 mg/l in April 2016 at upstream area where the lowest value was 10.84 mg/l in June 2016 at middle stream area. The higher COD value of the Bhairab River water may be due to massive municipal sewage, market waste and industrial run off coming into the river. In this study, the average value exceeds the standard value of COD that indicates the extreme pollution of the river and obviously a great threat to aquatic ecosystem.

3.9 *Dissolved oxygen*

DO refers to the oxygen that is dissolved in the water bodies and made available to aquatic life. The condition of low level oxygen in water is called hypoxia whereas high level oxygen in water is termed as anoxia. However, hypoxia causes fishes to be stressed, even to die (Roy et al., 2014). The optimum value of DO for good water quality is reported to be 4–6 mg/l where most fishes can live (Hoque et al., 2012). DO level below 3 mg/l in water body is of concern because of suffocation while DO level below 1 mg/l is devoid of most of the aquatic creatures (Website of EPA, 2020). According to DOE standard, DO values should be above 6.0 mg/l for drinking water and more than 5.0 mg/l is suggested for fisheries, recreation and irrigation (EEA, 1999). The DO values of different study times are shown in Figure 5. In our study, the values of DO of the Bhairab River ranged from 3.6 mg/l to 6.1 mg/l. The average value of DO was found to be 4.9 mg/l. The highest value of DO (6.1 mg/l) was observed in May 2016 while the lowest value (3.6 mg/l) in July 2016. The average DO value indicates that the river water is suitable for fishes and other aquatic organisms and unsuitable for drinking.

3.10 Turbidity

Turbidity, cloudiness of water, is caused by suspended solids (mainly soil particles) and colloidal matter that includes clay, finely divided organic as well as inorganic matter, and plankton (microscopic plants and animals) (Tareq et al., 2013). In most waters, turbidity occurs due to colloidal and extremely fine dispersions of solid materials (Mezgebe et al., 2015). Turbidity blocks out the light needed by submerged aquatic vegetation and raises the surface water temperatures. According to Bangladesh standard for water quality parameters, the permissible level of turbidity of river water is 10.0 NTU (Website of DPHE, 2020). The turbidity values of different study locations are shown in Table 2. In this study, the highest value of turbidity was observed to be 785.3 NTU in April 2016 while the lowest value (238.7 NTU) was found in May 2016. The average value of turbidity was determined to be 554.4 NTU. The analysis shows that the water of Bhairab River is highly turbid.

3.11 Chromium

The presence of total chromium, the most crucial heavy metals, in drinking water is very much harmful for human health and also for the aquatic creatures. According to Bangladesh standard for water quality parameters, the standard value of chromium in drinking water is 0.05 mg/l (Website of DPHE, 2020). The extent of total chromium obtained at different study locations are shown in Table 2. In this study, the concentrations of chromium in all study points were much below the proposed water quality standards (0.05 mg/l).

3.12 Water quality index

Water quality index (WQI) indicates an overall quality of water at a certain place and time. It is considered as the most effective approach of quantifying water quality. It is determined by the weighted arithmetic method using a number of water quality parameters. The WQI can be calculated as follows (Akter et al., 2016; Tyagi et al., 2013):

$$WQI = \frac{\sum q_i w_i}{\sum w_i} \tag{1}$$

where q_i and w_i are quality rating scale and relative weight, respectively. However, q_i and w_i can be determined using the following equations:

$$q_i = \frac{C_i}{S_i} \times 100 \tag{2}$$

$$w_i = \frac{1}{S_i} \tag{3}$$

where C_i and S_i are defined as concentration of *i* parameter and standard value of *i* parameter, respectively.

Monitoring river water quality is a requirement to manage water quality as well as to facilitate decision making for the authority. In the present study, the WQI was measured using seven different parameters namely, pH, TDS, EC, turbidity, BOD, COD and DO. The WQI is supposed to simplify a complex dataset into easily comprehensible and usable information. It designates the suitability of water for drinking. Depending on the value of WQI, the water is divided into five categories such as, excellent ($WQI < 50$), good water ($50 < WQI < 100$), poor water ($101 < WQI < 200$), very poor water ($201 < WQI < 300$), and unsuitable for drinking ($WQI > 300$) (Akter et al., 2016). WQI for Bhairab River water in April, May, June, July, and August 2016 were determined to be 957.30, 1,258.57, 1,015.81, 905.16 and 1,135.72, respectively. The result shows that the values of WQI are very high, which signifies the water of Bhairab River is unsuitable for drinking purpose. Although the water can be used for domestic and other purposes, but still it needs perceptible monitoring to avoid increasing anthropogenic contamination. Similar recommendation was reported for Ganga Canal water and Mandakini River water in India (Dwivedi, 2017; Matta et al., 2017).

4 Conclusions

River is supposed to be the homogeniser of its surrounding area as well as natural environment. So, overall environmental condition of an area and influence of surface water can be envisaged by monitoring water quality parameters of river water of that locality. In this research, the pH of the water of Bhairab River was found to be in the range of 6.06 to 8.60 while TDS was in the range of 192.7 mg/l to 986.4 mg/l. The average value of EC (776.3 μS/cm) indicated that the studied water was polluted. The average BOD value (2.21 mg/l) implied that the water was suitable for irrigation, fisheries and other recreational purposes. The obtained value of WQI based on physico-chemical parameters mean that it is not suitable for drinking purpose. However, in order to lessen the bad impact on water quality as well as to reduce pollution-related problems, remedial measures should be taken so that the wastes (both liquid and solid) cannot be discharged or dumped in the river. The authors recommend not only to conduct community awareness building program against water pollution but also to perform systematic monitoring and evaluation of water quality parameters so that an effective waste management strategy in the studied area can be made.

References

Ahipathi, M.V. and Puttaiah, E.T. (2006) 'Ecological characteristics of Vrishabhavathi River in Bangalore (India)', *Environ. Geology.*, Vol. 49, No. 2, pp.1217–1222.

Akter, T., Jhohura, F.T., Akter, F., Chowdhury, T.R., Mistry, S.K., Dey, D., Barua, M.K., Islam, M.A. and Rahman, M. (2016) 'Water quality index for measuring drinking water quality in rural Bangladesh: a cross-sectional study', *J. Health Popul. Nutri.*, Vol. 35, p.4, DOI: 10.1186/s41043-016-0041-5.

Babatimehin, O.I., Eludoyin, A.O., Ekundayo, O.O. and Ekwere, N.J. (2020) 'Water quality and perception on use in Obafemi Awolowo University, Ile-Ife, Nigeria', *Interdisciplinary Environ. Rev.*, Vol. 20, No. 2, pp.100–117.

Biswas, B.K. and Mandal, B.H. (2014) 'Construction and evaluation of rainwater harvesting system for domestic use in a remote and rural area of Khulna, Bangladesh', *Int. Scholarly Res. Notices* [online] http://dx.doi.org/10.1155/2014/751952.

Chowdhury, Q.M. (2001) 'Water and environment', *Forum of Environmental Journalist of Bangladesh*, ISBN-983-756-004-8.

Das, B. (1997) *Fisheries and Fisheries Resources Management*, pp.153–155, Bangla Academy, Dhaka, Bangladesh.

de-Oliveira, D.A. and Galvão, P. (2019) 'Geometry and water quality of the unconfined aquifer near the Piracicaba River, Ipatinga/MG, Brazil', *HydroRes.*, Vol. 2, pp.31–39 [online] https://doi.org/10.1016/j.hydres.2019.11.003.

DoE (1997) *Environmental Quality Standards (EQS) for Bangladesh*, Department of Environment (DoE), Ministry of Environment and Forest, Government of the People's Republic of Bangladesh.

DoE (2016) *Surface and Groundwater Quality Report 2016*, pp.9–10, Department of Environment (DoE), Ministry of Environment and Forest, Government of the People's Republic of Bangladesh.

Dwivedi, A.P. (2017) 'Study of physic-chemical characteristics of water in River Mandakini', *IJARCS*, Vol. 4, No. 9, pp.1–6, DOI [online] http://dx.doi.org/10.20431/2349-0403.0409001.

ECR (1997) *The Environment Conservation Rules (ECR)*, pp.179–227, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh.

Etikala, B., Golla, V., Adimalla, N. and Marapatla, S. (2019) 'Factors controlling groundwater chemistry of Renigunta area, Chittoor District, Andhra Pradesh, South India: a multivariate statistical approach', *HydroRes.*, Vol. 1, pp.57–62 [online] https://doi.org/10.1016/j.hydres.2019.06.002.

European Environment Agency (EEA) (1999) *Environment in the European Union at the Turn of the Century*, Copenhagen, Denmark.

Ezugwu, C.K., Onwuka, O.S., Egbueri, J.C., Unigwe, C.O. and Ayejoto, D.A. (2019) 'Multi-criterial approach to water quality and health risk assessments in a rural agricultural province, southeast Nigeria', *HydroRes.*, Vol. 2, pp.40–48 [online] https://doi.org/10.1016/j.hydres.2019.11.005.

Google Maps (2020) [online] https://www.google.com/maps/@23.5037062,90.3475825,7z (accessed 8 September 2020).

Gupta, P.K. (2001) *Methods in Environmental Analysis*, Water, Soil, Air Agrobios Publication, India.

Hasan, I., Rajia, S., Kabir, K.A. and Latifa, G.A. (2009) 'Comparative study on the water quality parameters in two rural and urban rivers emphasizing on the pollution level', *Global J. Environ. Res.*, Vol. 3, No. 3, pp.218–222.

Hoque, M.M.M., Roy, S., Hoque, M.N. and Islam, M.Z. (2012) 'Assessment of some water quality parameters of Bansi River in monsoon and winter seasons', *J. Environ. Sci. Natural Resour.*, Vol. 5, No. 2, pp.53–57.

Khan, A.S., Hakim, A., Waliullah, Rahman, M., Mondal, B.H., Mamun, A.A. and Ahammed, F. (2019) 'Seasonal water quality monitoring of the Bhairab River at Noapara industrial area in Bangladesh', *SN Appl. Sci.*, Vol. 1, No. 586 [online] https://doi.org/10.1007/s42452-019-0583-4.

Khan, H.H. and Khan, A. (2019) 'Groundwater-surface water interaction along River Kali, near Aligarh, India', *HydroRes.*, Vol. 2, pp.119–128 [online] https://doi.org/10.1016/j.hydres.2019.12.001.

Khan, Z.H. (2010) *Assessment of Water Quality and Source of Pollution for Some Selected Rivers in Southern Region of Bangladesh*, MEngg thesis, Department of Water Resources Engineering, BUET, Bangladesh.

Lokahnde, R.S., Singare, P.U. and Pimple, D.S. (2011) 'Study on physico-chemical parameters of waste water effluents from Taloja industrial area of Mumbai, India', *Int. J. Ecosys.*, Vol. 1, No. 1, pp.1–9, DOI: 10.5923/j.ije.20110101.01.

Malik, N., Biswas, A.K. and Raju, C.B. (2013) 'Chemical composition and assessment of water quality in benthic environment of an Indian reservoir through multivariate statistical approach', *Interdisciplinary Envrion. Rev.*, Vol. 14, Nos. 3/4, pp.253–268 [online] https://doi.org/10.1504/IER.2013.058929.

Matta, G., Srivastava, S., Pandey, R.R. and Saini, K.K. (2017) 'Assessment of physicochemical characteristics of Ganga Canal water quality in Uttarakhand', *Environ. Dev. Sustain.*, Vol. 19, pp.419–431 [online] https://doi.org/10.1007/s10668-015-9735-x.

Mezgebe, K., Gebrekidan, A., Hadera, A. and Weldegebriel, Y. (2015) 'Assessment of physico-chemical parameters of Tsaeda Agam River in Mekelle City, Tigray, Ethiopia', *Bull. Chem. Soc. Ethiopia*, Vol. 29, No. 3, pp.377–385, DOI [online] http://dx.doi.org/10.4314/bcse.v29i3.5.

Mgbenu, C.N. and Egbueri, J.C. (2019) 'The hydrogeochemical signatures, quality indices and health risk assessment of water resources in Umunya District, Southeast Nigeria', *Appl. Water Sci.*, Vol. 9, p.22 [online] https://doi.org/10.1007/s13201-019-0900-5.

Mustapha, A., Driss, B. and Mohamed, B. (2013) 'Seasonal variations in physic-chemical parameters of water body Amghass II Province Ifrane Morocco', *Universal J. Environmental Res. Technol.*, Vol. 3, No. 6, pp.660–666.

Patil, P.N., Sawant, D.V. and Deshmukh, R.N. (2012) 'Physico-chemical parameters for testing of water – a review', *International J. Environ. Sci.*, Vol. 3, No. 3, pp.1194–1207.

Rahman, M.A. and Bakri, D.A. (2010) 'A study on selected water quality parameters along the River Buriganga, Bangladesh', *Iranica J. Energy Environ.*, Vol. 1, No. 2, pp.81–92.

Rahman, M.M., Sultana, K.R. and Hoque, M.A. (2008) 'Suitability sites for urban solid waste disposal using GIS approach in Khulna City, Bangladesh', *Proc. Pakistan Academic Sci.*, Vol. 45, No. 1, pp.11–22.

Roy, S., Banna, L.N., Hossain, M. and Rahman, H. (2014) 'Water quality of Narai Canal and Balu River of Dhaka City: an impact of industrialization', *J. Bangladesh Agril. Univ.*, Vol. 12, No. 2, pp.285–290.

Saifullah, A.S.M., Kabir, M.H., Khatun, A., Roy, S. and Sheikh, M.S. (2012) 'Investigation of some water quality parameters of the Buriganga River.', *J. Environ. Sci. Natural Resour.*, Vol. 5, No. 2, pp.47–52.

Sinha, S.N. and Biswas, M. (2011) 'Analysis of physic-chemical characteristics to study the water quality of a lake in Kalyani, West Bengal', *Asian J. Exper. Biologi. Sci.*, Vol. 2, No. 1, pp.18–22.

Tareq, S.M., Rahman, M.S., Rikta, S.Y., Islam, S.M.N. and Sultana, M.S. (2013) 'Seasonal variations in water quality of the Ganges and Brahmaputra River, Bangladesh', *Jahangirnagar Univ. Environ. Bul.*, Vol. 2, pp.71–82.

Tyagi, S., Sharma, B., Singh, P. and Dobhal, R. (2013) 'Water quality assessment in terms of water quality index', *Am. J. Wat. Resour.*, Vol. 1, No. 3, pp.34–38, DOI: 10.12691/ajwr-1-3-3.

Uddin, M.A. (2015) *Study on Water Quality of Bhairab River in Khulna Region*, MSc thesis, Khulna University of Engineering and Technology [online] http://hdl.handle.net/20.500.12228/268.

Uddin, M.R., Hossain, M.Z., Akter, S., Ali, M.E. and Ahsan, M.A. (2020) 'Assessment of some physicochemical parameters and determining the corrosive characteristics of the Karnaphuli estuarine water, Chittagong, Bangladesh', *Water Sci.*, Vol. 34, No. 1, pp.164–180 [online] https://doi.org/10.1080/11104929.2020.1803662.

Website of Average Weather (2020) *Worldwide Largest Temperature Database* [online] https://www.average-weather.com/en/asia/bangladesh/jessore/?unit=metric (accessed 6 September 2020).

Website of DPHE (2020) *Homepage of Department of Public Health Engineering (DPHE), Government of Bangladesh* [online] https://old.dphe.gov.bd/index.php?option=com_content&view=article&id=125&Itemid=133 (accessed 4 September 2020).

Website of Elevation Map (2020) [online] https://elevationmap.net/noapara-manirampur-jessore-bd-1000107436 (accessed 6 September 2020).

Website of EPA (2020) *National Aquatic Resource Surveys of United States Environment Protection Agency (EPA)* [online] https://www.epa.gov/national-aquatic-resource-surveys/indicators-dissolved-oxygen (accessed 20 July 2020).

World Health Organization (WHO) (2004) *Guidelines for Drinking Water Quality*, 3rd ed., p.516.