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# ASSESSMENT OF SEASONAL WATER QUALITY VARIATIONS OF HIGHLY POLLUTED RIVERS IN BANGLADESH USING FEWS BANGLADESH SYSTEM

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## ABSTRACT

Regular monitoring and systematic analysis of river water quality data is a prerequisite for the development of effective pollution prevention strategies to protect the rivers around the world. This study endeavours to assess the pollution status of two important rivers in Bangladesh by using a new water quality information system, FEWS-Bangladesh. FEWS-Bangladesh is a customised version of the Delft-FEWS software developed by Deltares. In this syudy, monthly water quality data of the rivers Buriganga and Shitalakhya at 12 monitoring stations for the 2002-2017 period were collected from the Department of Environment (DoE) and Bangladesh Water Development Board (BWDB). Later, available data of significant water quality parameters of the rivers were imported into FEWS Bangladesh system. The study has found that FEWS-Bangladesh is an effective tool which allows for a wide range of analyses of water quality data. This includes an assessment of spatial and temporal variations of water quality using time series graphs and spatial maps displayed by the system. Data show that during the dry season (November to April), the Buriganga and Shitalakhya rivers are extremely polluted with very low dissolved oxygen (DO) values and significantly high biochemical oxygen demand ($BOD_5$) and chemical oxygen demand (COD) levels than Bangladesh Water Quality Standards (ECR, 1997). In addition, high fluctuation of the $BOD_5$ and COD values in both the Buriganga and Shitalakhya Rrivers are observed between the dry and wet seasons. The pollution level is found relatively higher at the middle portion of the Buriganga river (Kamrangirchar, Sadarghat, Dholaikhal area), as compared to both the upstream and downstream portions. In case of Shitalakhya river, the stations at the lower reach is found more polluted than the upper reach. Water quality of these rivers appears to be deteriorating with time.This study not only investigates the recent pollution conditions of two major rivers around Dhaka city but also highlights the needs to improve the existing water quality monitoring and information systems through wider use of the FEWS-Bangladesh system and to take action in order to improve water quality of the contaminated rivers in Bangladesh.

***Keywords:*** *Water quality, FEWS Bangladesh system, Delft-FEWS, Time series, Spatial map.*

## 1. INTRODUCTION

With increasing pollution load from domestic and industrial sources, quality of surface water and groundwater is becoming a major concern, particularly in developing countries like Bangladesh (Uddin et al., 2015). Bangladesh is a deltaic land crisscrossed by numerous rivers; the land is also consistently nourished by their water flows (Matin, 2005).Therefore, river water is one of the vital natural resources of this country, being used for drinking and domestic purposes, irrigation, survival of aquatic life, and development of industries. Dhaka city, the capital of Bangladesh, is surrounded by a circular river system, which includes the Turag River, the Buriganga River, the Dhaleswari River, the Balu Rriver, the Shitalakhya River, and the Tongi Khal (Rahman and Hossain, 2007). However, due to the lack of proper waste management, these rivers continuously receive untreated domestic and industrial wastewater. As a result, water quality of the rivers surrounding Dhaka has significantly degraded. Previous studies show that the water of the rivers Buriganga, Shitalakhya, Turag, and Balu are extremely polluted, particularly during the dry season (Kamal, Malmgren-Hansen and Badruzzaman, 1999); (Karim et al., 2000), (Magumdar, 2005); (Ahmed & Badruzzaman, 2007). The polluted water of these rivers has not only destroyed aquatic ecosystems but also poses health hazards to the dwellers of the city.  Reversing the declining trend of the rivers around Dhaka city has become a national priority to ensure the multifaceted use of river water as a resource.

The impact of pollution on the water quality of rivers depends on several factors, including types, sources, quantity of pollution discharged, as well as characteristics of the river in question (e.g., discharge). Successful improvement of surface water quality relies on the development of effective and feasible pollution control strategies that require a good understanding of the extent of pollution (Alam, Badruzzaman & Ali, 2012). In this regard, designing a good monitoring network to regularly observe the temporal and spatial variation of the important water quality parameters is essential for assessing the pollution status of the rivers. Although a handful of organizations in Bangladesh i.e. Department of Environment (DoE), Bangladesh Water Development Board (BWDB), and Dhaka Water Supply and Sewerage Authority (Dhaka WASA) collect monitoring data on the water quality of rivers, these data are not systematically stored or analysed to provide an insight to the full extent of pollution and its impact, such as the identification of pollution hot spots and locations where water quality standards are exceeded (UNDP, 2016). On this backdrop, this study uses a new water quality information system, called FEWS-Bangladesh, to assess the temporal and spatial trends of water quality in two major rivers around Dhaka city: the Buriganga River and the Shitalakhya River.

## 2. DELFT-FEWS AND THE FEWS-BANGLADESH SYSTEM

Delft-FEWS is an open data handling platform which has been developed by Deltares, an independent institute for applied research in the fields of water and the subsurface in the Netherlands. Essentially, Delft-FEWS comprises of modules that can be configured for building a hydrological forecasting system and can be customised to meet the specific requirements of a designated organization (Werner et. al., 2013). Initially developed for flood, drought and seasonal forecasting, FEWS is now widely used for analysis of water quality and other environmental data because of its unique characteristics concerning data importing, processing and model connections. In addition to its role as a flood forecasting tool, Delft-FEWS has also been extended for use as a water quality forecasting tool in the Netherlands, Singapore and South-Korea; as a groundwater scenario management tool in the National Groundwater Modelling System in England and Wales, as well as in Colombia and Canada; as a drought forecasting system in areas such as the River Po, Italy; and as a Water Information System for a number of Water Boards in the Netherlands (Werner et.al., 2013). It is a freely available software that handles large amounts of data efficiently, provides for consistent data quality, standardised work processes, visualization and reporting (Delft-FEWS Detares Nederlands, 2015). FEWS-Bangladesh is a customised system, tailor-made to fit DoE and Dhaka WASA's needs. It has been developed to be used as a water quality information system, allowing users to import, visualise, analyse and report on water quality of the rivers of Bangladesh. The system was developed as part of the "Innovative monitoring and reporting for Sustainable Water quality of the Meghna River (ISWAM)" project and was also applied in the project "Strengthening Monitoring and Enforcement in the Meghna River for Dhaka's Sustainable Water Supply", both led by Deltares in Bangladesh (Deltares Public Wiki, 2018).

## 3. METHODOLOGY

This section provides a description of the methods followed in the study.

### 3.1 Description of Study Area

Dhaka, the capital and largest city of Bangladesh, is located in central Bangladesh, on the eastern banks of the Buriganga River. The city lies on the lower reaches of the Ganges Delta and covers a total area of 306.38 square kilometres (118.29 sq mi). As part of the Bengal plain, the city is bounded by four rivers: Buriganga, Turag, Dhaleshwari, and Shitalakhya. The Buriganga River is one of the most important rivers for Dhaka. It originates from the Dhaleshwari River and is a tide-influenced river flowing west and then south of Dhaka. It is only 27 km long and its average width and depth are 400 m and 10 m, respectively. Its catchment area is 253 $km^2$. Most of the industries in Dhaka are located along the Buriganga and they release their untreated wastewater directly into this river. The river also receives domestic wastewater and pollution inputs from numerous non-point sources. The Shitalakhya River is a tributary of the Brahmaputra River. The length, average width and depth of this river are 110 km, 300 m, and 21 m, respectively. It flows by the eastern side of Dhaka District and falls into the Dhaleshwari River at Madanganj, near Narayanganj. The river joins the Balu River at Demra, a small tributary flowing from the north of greater Dhaka. Approximately 20 km downstream of Demra, the Shitalakhya River joins the Dhaleshwari River. The intake point of the largest surface water treatment plant in Dhaka, the Saidabad Water Treatment Plant, is along the Shitalakhya River.

### 3.2 Data Collection

Water quality data of the Buriganga and Shitalakhya Rivers were collected from DoE and BWDB.

DoE is a government department under the Ministry of Environment Forest and Climate Change, which is responsible for the protection of the environment. DoE conducts monthly monitoring of the water quality of 27 rivers at 63 locations for basic parameters: pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Suspended Solids (SS), Total Dissolved Solids (TDS) and Electrical Conductivity (EC), as well as periodic monitoring of chloride ($Cl^-$), turbidity and alkalinity (UNDP, 2016). The BWDB is a government agency under the Ministry of Water Resources that is responsible for surface water and groundwater management in Bangladesh. BWDB monitors temperature, DO, pH, $BOD_5$, turbidity, iron (Fe), $Cl^-$, EC and TDS at 29 stations, twice monthly (UNDP, 2016).

The locations of the monitoring stations and the period of data collection at each of the two selected rivers are presented in Table 1 and illustrated in Figures 1 and 2.

### 3.3 Water Quality Parameters Considered

This study considered selected physical and chemical parameters to assess the state of water quality of the rivers. The parameters were selected primarily based on data availability from both the BWDB and DoE, and the importance of the parameters as water quality indicators. EC and TDS are physical parameters of interest in this study. DO, $BOD_5$, COD, and are considered in this study. DO is a key water quality indicator as it is essential for the survival of fish and other aquatic organisms. The trend in DO may be regarded as an indicator of the overall trend in water quality (Luo et al., 2011). $BOD_5$ is a measure of biodegradable organics present in water, while COD is a measure of both biodegradable and non-biodegradable organics present in water (Davies, Abolude & Ugwumba, 2008).

Table 1: Monitoring stations along the studied rivers with parameters and data collection period.

| | Site ID | Site Description | Latitude | Longitude | Prameters | Period (years) |
|---|---|---|---|---|---|---|
| **Buriganga River** | BG-100 | Dhaka Mill Barrak | 23.67 | 90.44 | DO, $BOD_5$ and COD | 2001-2012 |
| | BG-101 | Mirpur Bridge | 23.79 | 90.33 | | 2015-2017 |
| | BG-102 | Hazaribagh | 23.60 | 90.44 | | 2015-2017 |
| | BG-103 | Kamrangir Char | 23.71 | 90.35 | | 2015-2017 |
| | BG-105 | SadarGhat | 23.70 | 90.41 | | 2015-2017 |
| | BG-106 | Bangladesh China Friendship Bridge | 23.68 | 90.42 | | 2015-2017 |
| | BG-107 | Dholaikhal | 23.70 | 90.40 | | 2015-2017 |
| | BG-108 | Pagla | 23.66 | 90.45 | | 2015-2017 |
| **Shitalakhya River** | SL-100 | Narayonganj | 23.66 | 90.52 | | 2001-2012 |
| | SL-101 | Demraghat. | 23.72 | 90.50 | | 2015-2017 |
| | SL-102 | Ghorashal Fertilizer Factory | 23.90 | 90.63 | | 2015-2017 |
| | SL-103 | Near ACI Pharmaceuticals. | 23.63 | 90.51 | | 2015-2017 |

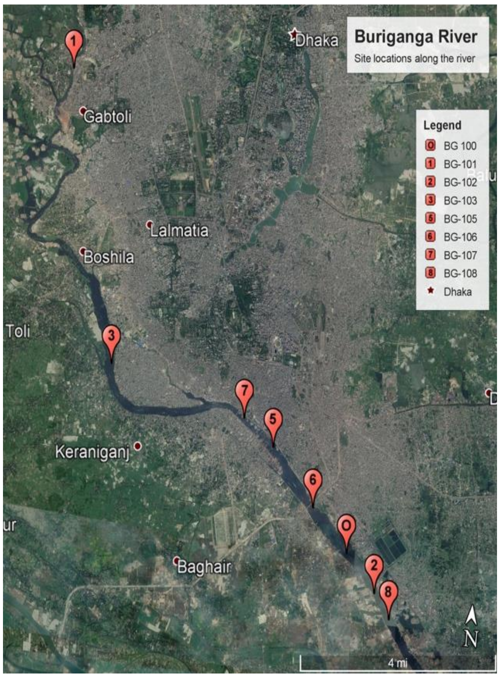



Figure 1: Locations of monitoring stations along the Buriganga River.

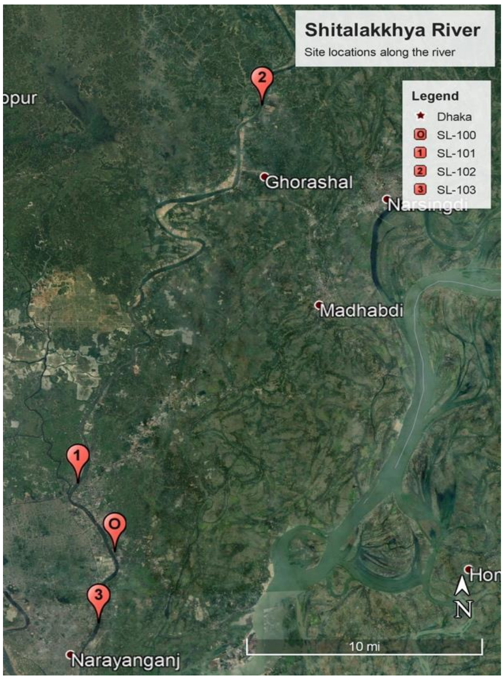



Figure 2: Locations of monitoring stations along the Shitalakhya River.

### 3.4 Water Quality Data Analysis Using FEWS-Bangladesh System

After collecting the required data from DoE and BWDB, FEWS-Bangladesh was used to analyse the data and generate important water quality information about the studied rivers. The steps followed in analysing data using FEWS-Bangladesh are presented in a flow chart illustrated in Figure 3:

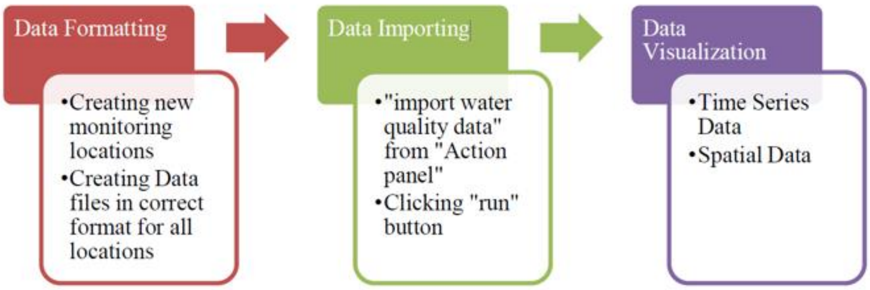



Figure 3: Flow chart for analysing data using FEWS Bangladesh system.

The flow chart in Figure 3 shows that a three-step procedure was followed in data analysis. Firstly, the information about the studied monitoring stations were added into the system and the collected data from all these stations were organised in the specified format of the system. Secondly, the formatted data files were imported to the system. Finally, the imported data were visualised in the display of the system as time series and spatial data.

## 4. RESULTS AND DISCUSSION

This section presents the water quality status of the Buriganga and Shitalakhya Rivers based on the analysis of the available data using the FEWS-Bangladesh System.

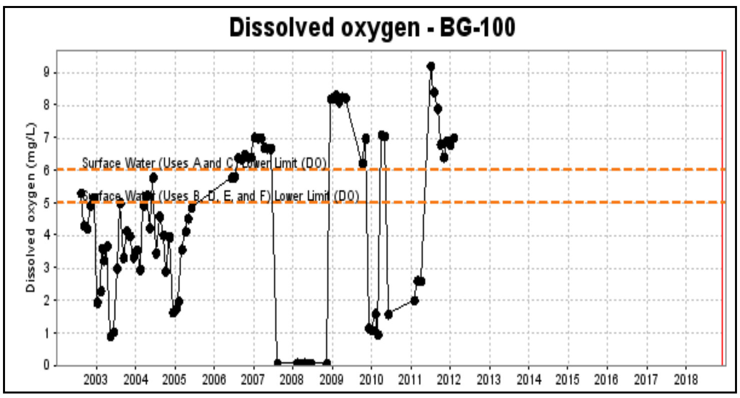
### 4.1 Water Quality Assessment of Buriganga River

Water quality data of Buriganga River were collected from 8 different monitoring stations of DOE and BWDB (locations of the stations are shown in Table 1).

#### 4.1.1 Dissolved Oxygen (DO)

Figure 4 demonstrate the time series of monthly measured values of DO at two monitoring stations along the Buriganga River.

(a)



(b)

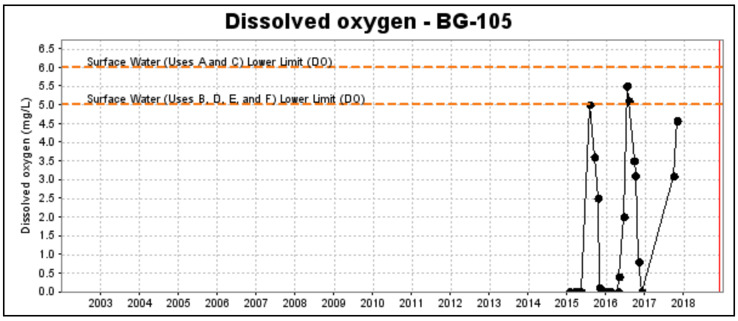



Figure 4: Time series of monthly DO concentration (mg/L) of Buriganga River at stations (a) BG-100 from 2002 to 2012 and (b) BG-105 from 2015 to 2017

Figure 4(a) shows that for the 2002-2012 period, the concentration of DO at the BG-100 station of the Buriganga River remained significantly low during pre-monsoon season (January to April) and post monsoon (October-December) season fluctuating within a range 0.06-3.0mg/L, whereas, during the monsoon season (May-September) the DO concentration was found relatively higher in the range of 4.0-9.00 mg/L. DO at BG-105, shown in Figure 4(b), indicates that during recent years (2015-2017), DO has almost always been below 5 mg/L, reaching a minimum DO level near zero during the dry season (November to April). During the wet season (May to October), DO remained within the range 2.18-5.20 mg/L. The trend of DO concentration between 2015-2017 was found to be similar for the six other stations along the Buriganga River. In addition to time series graphs of individual locations, the spatial distribution of water quality was observed by displaying all of the imported data in a single map produced by the FEWS-Bangladesh System. For instance, Figures 5 and 6 present the spatial variation of DO concentration at eight different monitoring locations along the Buriganga River in the months of February and October 2016, respectively. As discussed earlier, at all the monitoring stations, DO was found to be relatively low in dry season as compared to wet season**.**

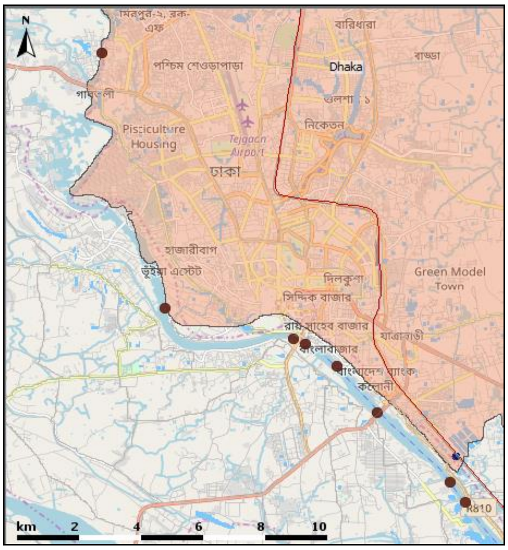



Figure 5: Spatial variation of DO levels (mg/L) along the Buriganga River (dry season).

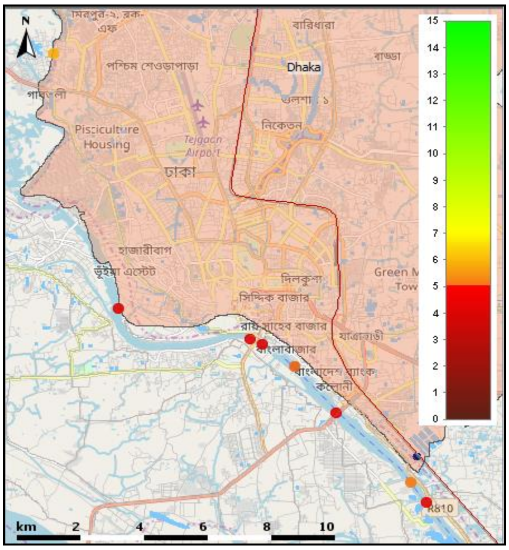



Figure 6: Spatial variation of DO levels (mg/L) along the Buriganga River (wet season).

In Figure 5, the stations are marked with dark red colour, indicating a DO level between 0-2.0 mg/L in February 2016 (pre-monsoon season), whereas in Figure 6, the same stations are marked with red or orange colour indicating a DO level between 3.0-6.0 mg/L in October 2016 (monsoon season). Figures 5 and 6 indicate that stations at the middle reach of the river are more contaminated (DO level below 5.0 mg/L) in both the pre-monsoon and monsoon seasons, compared to the stations at the upstream and downstream ends of the river. It should be mentioned that the scale of a particular parameter was selected in FEWS Bangladesh system configuration based on environmental regulations in Bangladesh (e.g. red is below water quality standards, orange is above water quality standards).

### 4.1.2 $BOD_5$ and COD

Figures 7, 8 and 9 present the monthly average **$BOD_5$** level observed at eight monitoring locations along the Buriganga River in 2016. $BOD_5$ levels at the monitoring locations varied between a range of 10-50 mg/L in the pre-monsoon period (stations marked with red colour in Figure 7). As expected, $BOD_5$ levels decreased during the monsoon and remained within a range 3.0-4.0 mg/L (stations marked with light green colour in Figure 8), which increased to a level between 4.5-7.0 mg/L in the post-monsoon period (stations marked with yellow/orange colour in Figure 9). Furthermore, from the time series and spatial variation of $BOD_5$ along the Buriganga River, significantly higher $BOD_5$ levels (above 30 mg/L) were found at BG-102 (Hazaribagh), BG-103 (Kamrangichar), BG-105 (Sadarghat) and BG-106 (Near Bangladesh China Friendship bridge) stations, which suggest that these locations are more polluted with biodegradable organic matter from sewage or other discharges. The overall $BOD_5$ level (>2.00mg/L, below standard water quality) of the Buriganga River is an indication of poor water quality throughout the year (ECR Schedule-3(A), 1997).

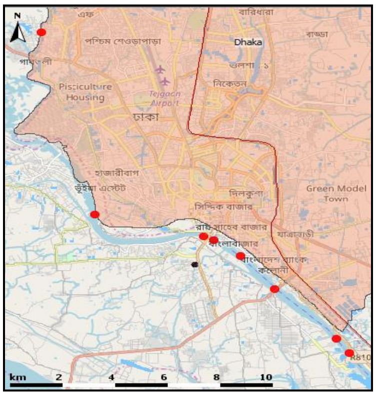



Figure 7: Spatial variation of BOD5 along the Buriganga River (pre-monsoon).

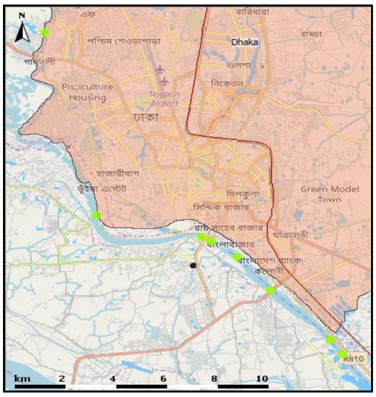



Figure 8: Spatial variation of BOD5 along the Buriganga River (monsoon).

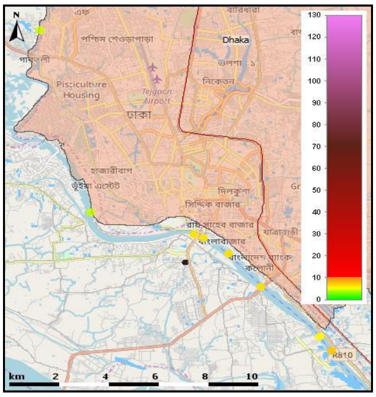



Figure 9: Spatial variation of BOD5 along the Buriganga River (post-monsoon).

Figures 10 and 11 demonstrate that COD levels in the Buriganga River at all of the monitoring stations were considerably high in the pre-monsoon period, fluctuating with a range of 40-80 mg/L (stations marked with red colour in Figure 10) and then decreased to 10-20 mg/L during the monsoon season (stations marked with yellow colour in Figure 11). Significantly higher COD levels (above 70 mg/L) were observed at stations located in the middle part of the river, indicating higher level of pollution.

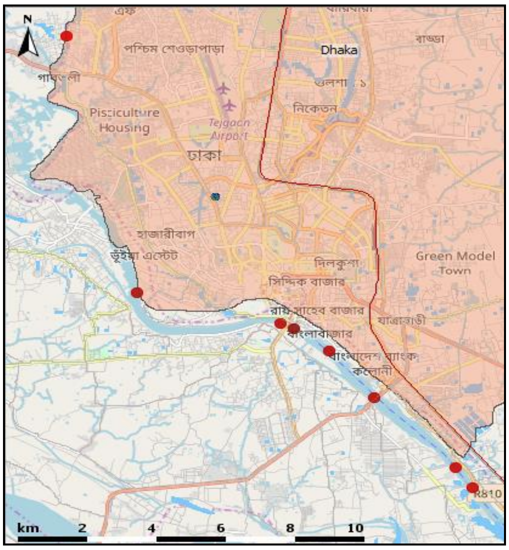



Figure 10: Spatial variation of COD levels along the Buriganga River (pre-monsoon).

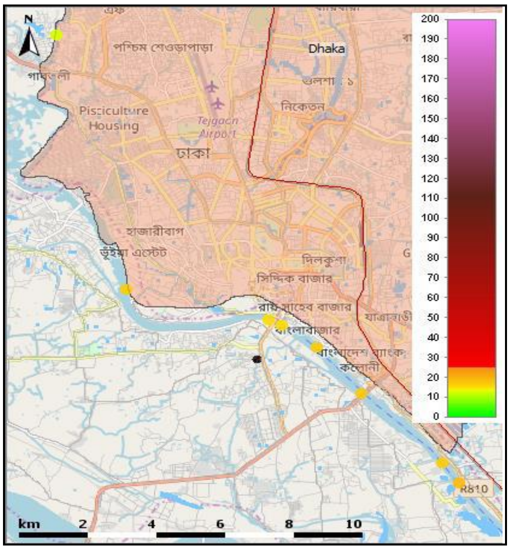



Figure 11: Spatial variation of COD level along the Buriganga River (monsoon).

## 4.2 Water Quality Assessment of Shitalakhya River

Water quality data of Shitalakhya River were collected from 4 different monitoring stations of DOE and BWDB (locations of the stations are shown in Table 1).

### 4.2.1 Dissolved Oxygen (DO)

Figures 12 and 13 illustrate the spatial variation of DO concentrations observed at the monitoring stations along the Shitalakhya River in May and October 2016, respectively. It is seen that DO levels fluctuated between 2.0-4.0 mg/L at the outset of monsoon, which increased to a level between 5.0-6.0 mg/L after the monsoon in 2016. DO levels at the lower reach of the Shitalakhya River most often remained below 5 mg/L; the DO level fluctuated between 3.2-7.0 mg/L at the upper reach of the river. The average DO level of the Shitalakhya River is an indication of poor water quality of the river year-round (ECR Schedule-3(B), 1997].


Figure 12: Spatial variation of DO along the Shitalakhya River (dry season)

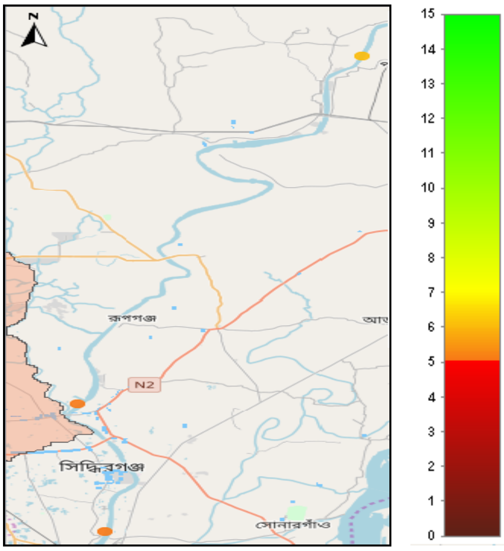



Figure 13: Spatial variation of DO along the Shitalakhya River (wet season)

### 4.3 $BOD_5$ and COD

From the spatial variation of $BOD_5$ at the monitoring locations along the Shitalakhya River in the months of February and September 2016, presented in Figures 14 and 15, it is seen that $BOD_5$ levels varied between a range 15-30 mg/L in the pre-monsoon season, decreasing to 0.8-1.10 mg/L in the monsoon period. $BOD_5$ levels in the Shitalakhya River during the dry season (>10 mg/L, the maximum value for a surface water body according to Bangladesh standards) limits its use for any purpose (ECR Schedule-3(A), 1997).


Figure 14: Spatial variation of BOD along the Shitalakhya River (dry season)

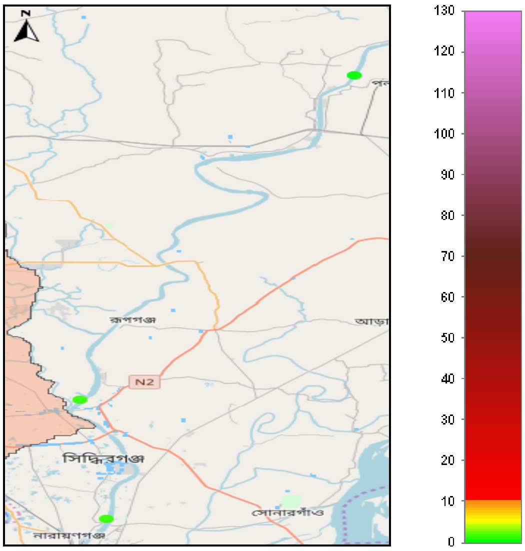



Figure 15: Spatial variation of BOD along the Shitalakhya River (wet season)

Figures 16 and 17 show that like $BOD_5$, COD levels in the Shitalakhya River at all the monitoring locations are considerably higher in the pre-monsoon period, fluctuating within a range 30-60 mg/L (stations marked with red colour in Figure 16); COD values then decreased to 16-30 mg/L during the monsoon season (stations marked with orange and red colour in Figure 17).


Figure 16: Spatial variation of COD along the Shitalakhya River (dry season)

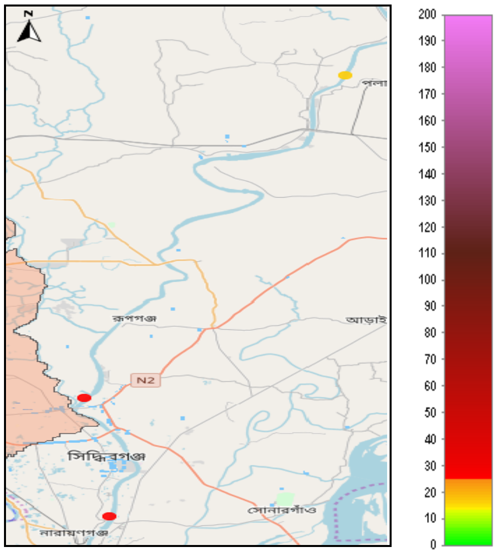



Figure 17: Spatial variation of COD along the Shitalakhya River (wet season)

## 5. CONCLUSIONS

This research focused on the assessment of water quality of the Buriganga and the Shitalakhya Rivers using FEWS-Bangladesh system with an insight to the effectiveness of the FEWS-Bangladesh System as an innovative technique to handle and interpret monitoring data in order to generate useful water quality information about the rivers in Bangladesh. It has been found that, the FEWS-Bangladesh System is an effective water quality information system, since it displays both raw water quality data, as well as daily, quarterly, monthly and yearly averages as time series and in a spatial display. The system can be configured to display the data in a wide range of formats, as needed. It is thus possible to easily identify locations with higher pollution levels using the spatial display available in the system.

The water quality status of the Buriganga River, flowing from the west to the south of Dhaka, has deteriorated significantly in recent years. High fluctuation of $BOD_5$ and COD values in both the Buriganga and Shitalakhya River were observed between the dry and wet seasons. The Buriganga River has been found to be polluted throughout the year, with significantly lower DO levels and higher $BOD_5$ and COD values than the acceptable level of a good raw water source for water supply. In addition, pollution is severe in the middle portion of the river (Kamrangirchar, Sadarghat, Dholaikhal area), as compared to both the upstream and downstream portions. In the case of the Shitalakhya River, water quality at the monitoring stations in the upper reach of the river was found to be better during the wet season, but not during the dry season. However, at the stations in the lower reach of the river, the $BOD_5$ level was found to be within the acceptable limit (according to Bangladesh standard) during the wet season, whereas DO levels were below the standard during both the dry and wet seasons.

The study recommends that governmental agencies in Bangladesh involved in the monitoring of river water quality should adopt innovative technologies like the FEWS-Bangladesh System to display and systematically analyse and report on monitoring data. This will eventually help the policy makers to undertake effective pollution control and prevention strategies to protect the rivers in Bangladesh.

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## REFERENCES

Ahmed T. and Badruzzaman A.B.M. (2007), Effect of Thermal Effluent on Water Quality of Shitalakhya river. Journal of Civil Engineers, The Institution of Engineers, Bangladesh, 35(1), 59-70.

Alam, M., Badruzzaman, A. and Ali, M. (2012). Water Quality Response to Reductions in Waste Loading of Sitalakhya River, Bangladesh. Journal of Water and Environment Technology, 10(1), pp.31-46.

Bangladesh Potable Water Quality Standard [ECR, 1997, Schedule-3(B)] and WHO (2004) Guideline Values

Davies, O. A., Abolude, D. S. and Ugwumba, A. A. (2008). Phytoplankton of the lower reaches of Okpoka creek, Port Harcourt, Nigaria. Journal of Fisheries International. Vol. 3. Issue 3. pp 83-90.

Deltares Nederlands (2015) Retrieved from https://www.deltares.nl/app/uploads/2015/01/ Delft-FEWS_brochure-2017.pdf.

Deltares Nederlands (2018). Retrieved from https://oss.deltares.nl/web/delft-fews/implementations

Deltares Public Wiki. (2018). Retrieved from https://publicwiki.deltares.nl/pages/viewpage.action?pageId=127633757

Kamal, M., Malmgren-Hansen, A. and Badruzzaman, A. (1999). Assessment of pollution of the river Buriganga, Bangladesh, using a water quality model. Water Science and Technology, 40(2), pp.129-136.

Karim, M., Badruzzaman, A., Sekine, M. and Ukita, M. (2000). Assessment of nutrients and dissolved oxygen in a river system in Bangladesh using a water quality model. Doboku Gakkai Ronbunshu, (664), pp.97-107.

Luo, P., He, B., Takara, K., Razafindrabe, B., Nover, D. and Yamashiki, Y. (2011). Spatiotemporal trend analysis of recent river water quality conditions in Japan. Journal of Environmental Monitoring, 13(10), p.2819.

Magumdar.T.K. (2005), Assessment of Water quality in the Peripheral rivers of Dhaka city, M. Engineering Thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka.

Rahman, S. and Hossain, F. (2007). Spatial Assessment of Water Quality in Peripheral Rivers of Dhaka City for Optimal Relocation of Water Intake Point. Water Resources Management, 22(3), pp.377-391.

Standards for Inland Surface Water [ECR 1997, Schedule 3(A)]

Uddin, M., Alam, M., Mobin, M. and Miah, M. (2015). An Assessment of the River Water Quality Parameters: A case of Jamuna River. Journal of Environmental Science and Natural Resources, 7(1).

UNDP (2016). Report on Scoping Study on Environmental Health and Water Quality in Rivers and Ecologically Critical Areas in Bangladesh (p. 77).

Werner, M., Schellekens, J., Gijsbers, P., van Dijk, M., van den Akker, O. and Heynert, K. (2013). The Delft-FEWS flow forecasting system. Environmental Modelling & Software, 40, 65-77.