BAUET JOURNAL
Published by
Bangladesh Army University of Engineering & Technology
Journal Homepage: http://journal.bauet.ac.bd/

Assessing the Water Quality in Buriganga River applying Water Quality Index, Clustering and GIS

Ananna Hoque Shathi[1], Md. Shahid Uz Zaman[1] and Umme Rumman Chaity[2]

[1]*Department of Computer Science & Engineering, Rajshahi University of Engineering & Technology, Rajshahi-6204, Bangladesh*
[2]*Department of Computer Science & Engineering, Rajshahi University, Rajshahi-6205, Bangladesh*

Abstract: Bangladesh is recognized as a riverine country throughout the world. The Buriganga flowing beside the Dhaka city is the most salient river. In contrast with the past, it is one of the most contaminated rivers in Bangladesh. The majority of the industries and factories of Dhaka are on the bank of the river and they are polluting its water every day. In this paper, a research is carried out to determine and visualize the contamination level of water of the river using Geographical Information System (GIS) and clustering technique. The Water Quality Index (WQI) and the clustering approach are used to categorize the pollution levels of various monitoring stations of the river. Monitoring stations, clustered into different pollution levels, are visualized using GIS mapping. According to the obtained WQI values, three symbolic groups named less polluted, moderately and highly polluted sites are observed.

Keywords: *Cluster analysis; GIS; Pollution level; Water quality index*

Introduction: The Buriganga River is the central river flowing beside the Dhaka city, capital of Bangladesh. Because of the tanneries in the riverbank of Buriganga and for using the river as dumping ground for the liquid and solid wastes, the river is now under threat of extinction [1]. The Buriganga River has become heavy polluted from sources such as waste flowing into the river, oil spills from boats and building structures appearing on the river bank. It is now a dying river and the situation gets worse unless steps are taken urgently to reverse the trend. Declining water quality has become a global issue of concern as human populations grow, industrial and agricultural activities expand, and climate change threatens to cause major alterations to the hydrological cycle [2]. This paper's endeavor focuses on water quality detection and clustering the monitoring stations into groups to control pollution in the Buriganga River.

In recent years several researches has been initiated for the detection of water quality in different countries of southern part of Asia and also in Europe and America. Indrani Gupta, Awkash Kumar et al. [3] from India has worked on water quality detection on the Godavari river in 2015. They have studied various parameter of water like pH, DO, BOD and some other factors to differentiate the range of pollution level in Godavari River. Wen-Cheng Liu et al has proposed a new methodology for water quality measurement [4]. The work named, "Assessment of Water Quality in a Subtropical Alpine Lake Using Multivariate Statistical Techniques and Geostatistical Mapping: A Case Study", they have taken similar parameters like to index the quality of water [3]. Mohammad Moniruzzaman, Syed Fazle Elahib, Md. Abu Anis Jahangir had proposed a statistical methodology for the difference in the value of water quality parameters from year to year [5]. As a very few studies were conducted on water quality assessment of Buriganga river, the availability of such outcomes are very scary till the day. The research we have conducted will help with a little more information for the other researcher in a near future [6].

Article history:
Received 22 November 2017,
Received in revised form 21 December 2017
Accepted 30 December 2017,
Available online 30 March 2018

Corresponding author details:
E-mail address: anannahoque.cse10@gmail.com
Tel: +8801515679800

The aims of this study are classifying the pollution levels of the river , grouping the selected sites into three categories less polluted, moderately and highly polluted, visualizing clusters of monitoring stations derived using GIS through map, assisting in managing and controlling pollution in the Buriganga river.

Experimental: Water quality index is a 100 point scale which summarizes results from a total of nine different parameters such as Dissolved oxygen, Fecal coliform, pH, And Biochemical oxygen demand etc.

Table 1. Water Quality Ranges [Courtesy: National Sanitation Foundation]

Range	Water Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very Bad

According to National Sanitation Foundation (NSF), Water Quality Index is expressed by,

$$WQI = \sum_{i=1}^{n} W_i Q_i \qquad \text{eq. 1}$$

Where $\sum W_i = 1$, W_i = Weighting Factor, Q_i =the rating value of parameter i, n = number of parameters.

Table 2. Water Quality Factors and Weights [Courtesy: National Sanitation Foundation]

Factor	Weight
Dissolved Oxygen (DO)	0.17
Fecal Coliform	0.16
pH	0.11
Biochemical Oxygen Demand (BOD)	0.11
Temperature Change	0.10
Total Phosphate	0.10
Nitrates	0.10
Turbidity	0.08
Total solids	0.07

A Clustering algorithm attempts to find natural groups of components (or data) based on some similarities [8]. Hierarchical clustering methods impose a hierarchical structure on the data objects and their step-wise clusters, i.e. one extreme of the clustering structure is only one cluster containing all objects, and the other extreme is a number of clusters which equals the number of objects. Ward's method is a criterion applied in hierarchical cluster analysis [9]. The initial cluster distances in Ward's method are therefore defined to be the squared Euclidean distance between points:

$$d_{ij} = d(\{X_i\},\{X_j\}) = \|X_i - X_j\|^2 \qquad \text{eq. 2}$$

There are many R programming language functions for cluster analysis such as, dist () -calculates a distance matrix for dataset, hclust () - performs hierarchical clustering on a distance matrix performing a cluster analysis from raw data [11]. The basic hierarchical clustering function is `hclust ()`, which works on a dissimilarity structure as produced by the `dist ()` function.

Result and Discussion:

The Water Quality Parameters of eight monitoring stations of Buriganga River have been collected from Laboratory, Department of Environment, Dhaka Division, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh. Although data have been collected for the twelve months of the year, the parameters for month June during the year 2015 rendered here.

Table 3. Water Quality Parameters for the month June, 2015[10]

St. no.	Station Name	Temp.	pH	DO	BOD	Total Solids	Turbidity
1	Mirpur Bridge	29.9	7.24	2.3	4.4	87.2	45
2	Hazaribagh	30	7.21	1.6	8	121.4	27
3	Kamrangirchar	29.9	7.49	2	0.6	117.9	21
4	Chadnighat	29.8	7.49	1.5	6	118.1	18
5	Sadarghat	29.9	7.46	1.9	12	120.6	14
6	Dholaikhal	29.9	7.44	1.2	7	123.4	17
7	China-Friendship Bridge	30	7.43	1.4	6	126.2	18
8	Pagla	29.8	7.53	0.8	8	126.5	20

Box and Whisker Plot

In the following figures, Box plot depicts the parameters pH, DO and BOD through their quartiles. Here, Box plots have lines extending vertically from the boxes (whiskers) indicating variability outside the upper and lower quartiles, hence the terms box-and-whisker plot and box-and-whisker diagram.

Fig. 1: Boxplot of pH

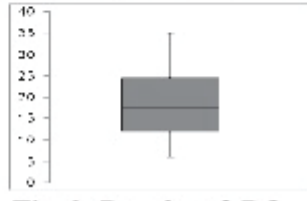

Fig. 2: Boxplot of DO

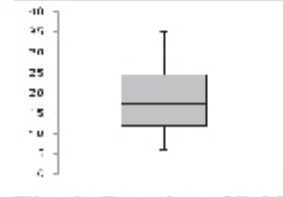

Fig. 3: Boxplot of BOD

Calculation of Water Quality Index

Table 4. Water Quality Indices of Buriganga River during 2013-2016

Station no.	Station Name	2013	2014	2015	2016	Avg. WQI
1	Mirpur Bridge	53	51	64	51	55
2	Hazaribagh	49	49	59	47	51
3	Kamrangirchar	48	45	60	47	50
4	Chadnighat	46	42	59	50	49
5	Sadarghat	50	48	57	51	52
6	Dholaikhal	44	42	54	56	49
7	China-Friendship Bridge	47	44	56	52	50
8	Pagla	55	44	52	50	51

Dendrogram

The clusters of the monitoring stations are represented in the following figures as dendrogram using R programming.

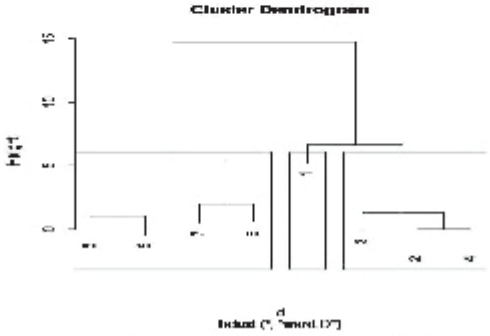

Fig. 4: Dendrogram for the year 2015

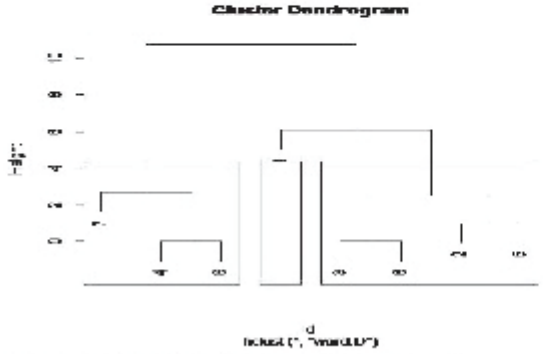

Fig. 5: Dendrogram for Average WQI

Mapping

Pollution levels of the monitoring stations during the year 2013 to 2015 are visualized through GIS map in ArcMap in ArcGIS 10.1.

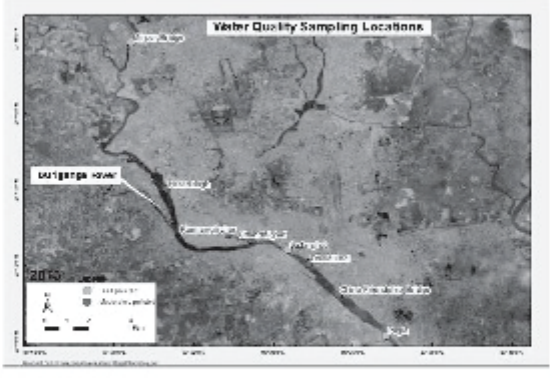

Fig. 6: Water Quality Classification of Buriganga River in 2013

In the above figure, it is shown that, the monitoring stations Mirpur Bridge, Sadarghat and Pagla are classified as less polluted for the year 2013. Hazaribagh, Kamrangirchar, Chadnighat, Dholaikhal and Bangladesh China-Friendship Bridge were moderately polluted monitoring stations. Pollution levels are shown with the green and blue colors. Green color represents the less polluted monitoring stations and blue color represents the moderately polluted monitoring stations.

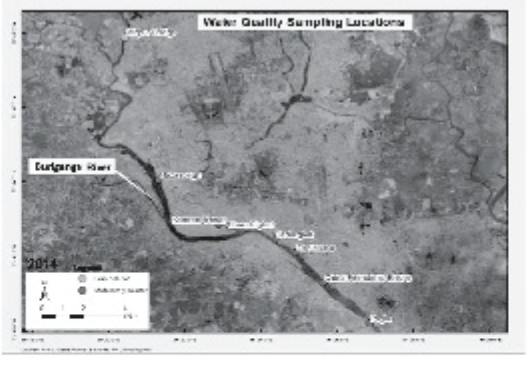

Fig. 7: Water Quality Classification of Buriganga River in 2014

In the year 2014, Mirpur Bridge is classified as less polluted. Sadarghat, Pagla, Hazaribagh, Kamrangir-char, Chadnighat, Dholaikhal and Bangladesh China-Friendship Bridge were moderately polluted.

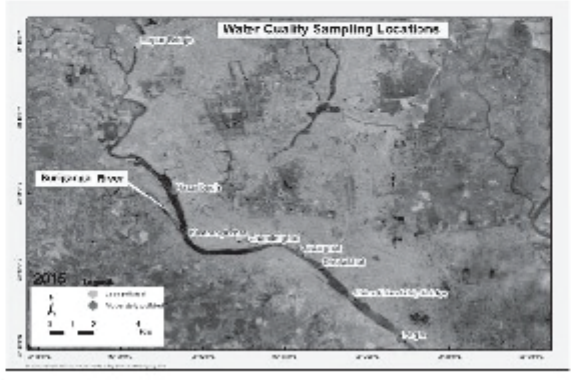

Fig. 8: Water Quality Classification of Buriganga River in 2015

The water quality in Buriganga River has deteriorated from time to time. The resultant map for year 2015 in fig 8 shows the overall pollution level of different stations of the river. The monitoring stations Mirpur Bridge, Kamrangirchar and Chadnighat are classified as less polluted. Hazaribagh, Sadarghat, Dholaikhal, Bangladesh China-Friendship Bridge and Pagla were moderately polluted monitoring stations. The clustering results are viewed in a GIS layer in ArcMap in the following figure:

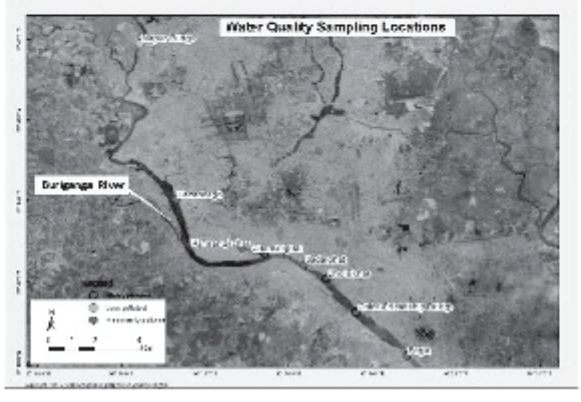

Fig. 9: Water Quality Classification of Buriganga River based on cluster analysis

Conclusion: The eight monitoring stations of Buriganga River are clustered according to National Sanitation Foundation's Water Quality Index and also cluster analysis. Cluster analysis provides a little change in result. After the completion up to this analysis, it is observed the pollution levels of the different locations of the Buriganga River has reached such a severe level of pollution which will peril the eco-system under water and also the living inhabitants dependent on the river. Visualization of the pollution sites and their pollution levels using GIS of the Buriganga River makes a major contribution for assessment of water quality network. Less polluted, moderately and highly polluted sites are detected into the map. The resultant maps may assist the decision makers in managing pollution in the Buriganga River.

Acknowledgements: Grateful acknowledgement is conveyed to Department of Environment, Dhaka Division, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh for providing necessary data for the work to be done.

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