

1 **Evaluation of the Surface Water Quality in Bangladesh with an Introduction of Water**
2 **Quality Index (WQI) and its Prediction from Limited Parameters**

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17

18 **Abstract**

19 Healthy aquatic environment is crucial for preserving aquatic lives in surface waters. Increasing
20 discharge or run-off from industrial or agricultural sources can pollute water leading to an
21 unhealthy aquatic environment that can cause distress in fishes and other aquatic lives. In places
22 with lack of infrastructure and regulatory enforcement, pollution can be particularly challenging
23 to handle. Assignment of an indexing system can be helpful for analyzing pollution pattern in the
24 polluted rivers which can be helpful for remediation purposes and prevention of future pollution.
25 Bangladesh currently does not have any indexing system in place. Assignment of indices in the
26 rivers of Bangladesh can be helpful for remediation of the rivers on a preferential basis as
27 remediation of all the rivers at once will pose challenges with funding and infrastructural
28 allocation. Parameters monitored in the water monitoring stations of ten rivers were extracted
29 from the reports published by the Department of Environment (DOE) of Bangladesh. A water
30 quality index (WQI) was assigned on the rivers across seven years of time period to identify the
31 most polluted rivers. The degree of pollution in the river was in the order of Mayuri > Buriganga
32 > Korotoa > Turag > Shitalakhya > Surma > Halda > Dhaleshwari > Mathavanga > Brahmaputra
33 based on the WQI analysis. The most polluted rivers were located in areas with manufacturing,
34 textile etc. industries. Hence, monitoring of industrial discharge into the rivers and regulatory
35 enforcement is crucial for the prevention of pollution in rivers. Installment of more monitoring
36 stations and more frequent samplings can be helpful for better assessment of WQI of the rivers.
37 However, deployment of these strategies can be challenging for Bangladesh due to funding and
38 infrastructural constraints. Hence, a formula has been derived in this study to calculate WQI in a
39 resource limited situation ($WQI = 4.42 - 0.42 \text{ Dissolved oxygen} + 0.11 \text{ Biochemical oxygen}$
40 demand).

41 **Keywords:** Water quality, water quality index, dissolved oxygen (DO), biochemical oxygen
42 demand (BOD), industrial discharge, pollution

43 **Highlights**

- 44 • Rivers located in industrialized areas were highly polluted
- 45 • The five most polluted rivers were Mayuri, Buriganga, Korotoa, Turag, and Shitalakhya
- 46 • Brahmaputra and Mathavanga were in good condition
- 47 • Water quality index (WQI) can be predicted using the relationship derived in this study.

48

49 **1. Introduction**

50 All living being need water for sustaining life. Quality of life is directly correlated to
51 accessibility of clean water [1]. However, to meet the increasing demand for food and various
52 products, demand for agricultural and industrial production is increasing with time which
53 consequently causes water pollution with high strength agricultural run-off and industrial
54 discharge into receiving water bodies [2]. With a lack of well-developed infrastructure and
55 regulatory enforcement, water pollution is particularly more prevalent in the developing
56 countries [3]. Moreover, remediation of polluted waterbodies also poses challenge for
57 implementation due to lack of financial resources [4]. However, use of polluted water for
58 everyday needs including for drinking, cooking, bathing, and irrigation is a common trend in the
59 developing countries [5]. This poses a public health risk along with a high risk associated with
60 sustaining healthy aquatic lives in the waterbodies. Hence, remediation of polluted waterbodies
61 is crucial for sustainable water resources management.

62 Bangladesh is relatively a small country consisting of about 700 rivers, including tributaries
63 flowing through it that are a key source of domestic, industrial, and agricultural water use [6].
64 These rivers are major role players in the advancement of economic growth of Bangladesh as
65 they provide multiple uses including transportation of goods and production materials [7].
66 However, rapid and unplanned urbanization and industrialization to meet the demands exerted by
67 an overly populous country resulted in an overabundant and unchecked pollution of the river
68 waters in Bangladesh with untreated discharge or run-off of chemical, industrial and agricultural
69 wastes, micro-organisms, or fecal matters [8,9]. In addition to the anthropogenic activities, river
70 water is also polluted for a combination of other factors such as geochemical factors, chemical
71 composition, and lithogenic structure [7,10]. About 80% of diseases in the world are caused due

72 to poor hygiene and contaminated water [6]. Water pollution negatively affects the quality of life
73 for both terrestrial and aquatic beings, directly or indirectly. Therefore, water quality needs to be
74 closely monitored and maintained for achieving sustainable economic and social development,
75 and preservation of terrestrial and aquatic beings.

76 Generally, river water quality can be evaluated based on several physical, biological, and
77 chemical parameters [7]. For instance, the National Science Foundation (NSF) recommends
78 evaluation of water quality by monitoring dissolved oxygen (DO), biochemical oxygen demand
79 (BOD), fecal coliform, pH, temperature, total phosphate, nitrate, turbidity, total solids etc. and
80 assigns weights to each parameters to determine the overall quality of a water body [11]. The
81 combination of the monitored parameters in different intensities helps define the status of
82 pollution and determine the degree of it for a certain surface water body [12]. Hence, a single
83 parameter assignment considering the monitored parameters and associated values can help
84 quantify the degree of pollution and water quality of a water body. Generally, the cumulative
85 assessment of the monitored parameters is quantified as an index termed as water quality index
86 (WQI) which is a useful tool for overall water quality evaluation [12]. The assignment of weights
87 on different parameters and which parameters are considered for WQI calculation can vary
88 across different kind of water quality monitoring agencies. WQI has been used as a strong tool
89 for water quality assessment in different countries for the purposes of aquatic ecosystems
90 preservation and monitoring of water usage for different purposes [1,13]. As discussed above,
91 assessment of water quality is often poorly structured in the developing countries. Consequently,
92 a universal WQI assignment and evaluation is seldom prevalent among the developing countries.
93 Similarly, Bangladesh currently monitors a few parameters only and there has been no attempt at
94 employment of WQI to assess water quality quantitatively and qualitatively in the country. A

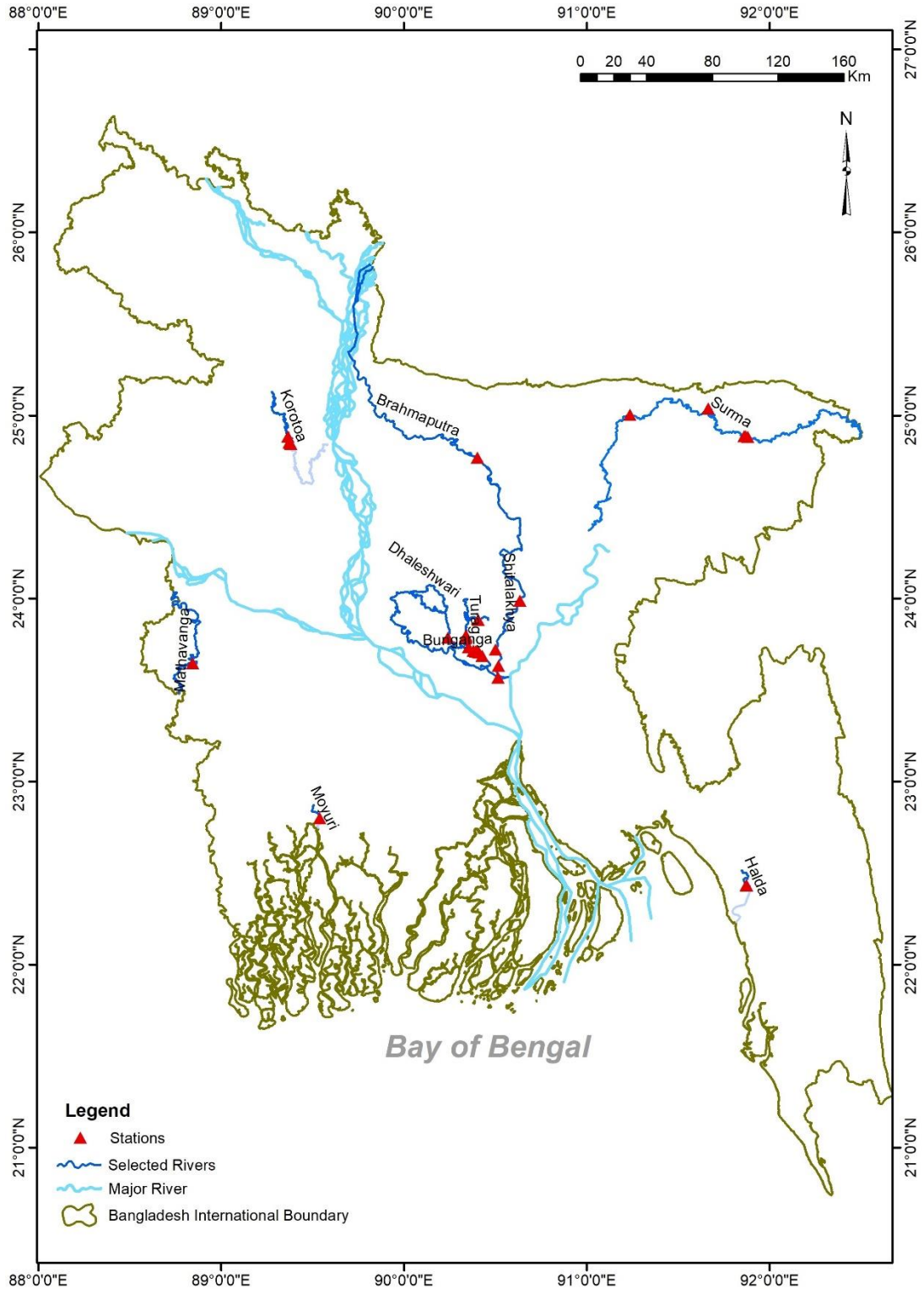
95 WQI particularly adopted for the monitored parameters in Bangladesh will be useful for
96 determining water quality and the degree of pollution in the rivers of Bangladesh. Evaluation of
97 the pollution level in different waterbodies will be helpful in remediation planning and
98 management by focusing on the most polluted waterbodies on priority basis.

99 The Department of Environment (DOE) of Bangladesh monitors some parameters at different
100 monitoring stations, but DOE does not assign WQI to the different waterbodies. There are
101 several published works on assigning WQI to different water sources in Bangladesh. Two of the
102 identified studies were focused on WQI for groundwater while other studies focused on WQI for
103 surface water. Iqbal et al. (2020) studied and assigned WQI for groundwater quality evaluation in
104 Bangladesh [14]. Assignment of WQI for groundwater quality evaluation in Tala Upazila in the
105 Sathkhira district covering a smaller geographical area has also been reported [15]. However,
106 surface water is the main resource for water usage in different sectors and it is directly correlated
107 to a well-preserved aquatic ecosystem. Hence, WQI assignment to surface water bodies will be
108 helpful for preservation of aquatic systems and remediation of the polluted waterbodies to
109 achieve sustainable water resources management [10]. Currently, there are limited studies
110 investigating different surface water quality parameters to employ WQI to surface waterbodies in
111 Bangladesh. Hossain et al. (2019) studied water quality of the Karnaphuli river by assigning
112 WQI at five different sampling locations of the river [16]. Similar studies were published on
113 WQI assignment based on selected parameters at different sampling locations of Buriganga,
114 Turag and Dhaleshwari rivers [17,18,19,20]. However, a more holistic approach for WQI
115 assignment on the main rivers and more widespread area of Bangladesh is yet to be employed.
116 Assignment of WQI to several major rivers, especially those located in industrialized areas, will
117 be helpful for identifying the rivers requiring the most focus for remediation. Moreover, trend

118 analysis of water quality by studying WQI of a number of rivers across a several years of time
119 period will help understand the overall timeline, degree of improvement or deterioration in the
120 rivers. Additionally, a simplified formula for WQI prediction with one or two parameters will be
121 helpful for countries like Bangladesh where monitoring of more parameters might be challenging
122 due to lack of funds and access to other resources. Therefore, the objective of this study is to (i)
123 analyze DO and BOD trend in the selected rivers, and (ii) assign and analyze WQI trend in ten
124 selected rivers and investigate the correlation of WQI with the observed parameters. A
125 correlation between WQI with one or two most frequently observed parameters (DO and BOD in
126 Bangladesh) will help evaluate water quality in a resource limited situation, especially in
127 developing countries, where monitoring of more parameters might be limited by availability of
128 funds and infrastructures.

129 **2. Methods**

130 Ten rivers were selected based on the availability of most data points both in terms of number of
131 parameters and timeline of data collection for trend analysis of parameters (DO and BOD) and
132 WQI calculation [Figure 1]. Moreover, the selected ten rivers were located in industrialized,
133 urban residential or agricultural areas. The ten selected rivers were Buriganga, Shitalakhya,
134 Turag, Dhaleshwari, Brahmaputra, Halda, Moyuri, Surma, Korotoa, Mathavanga. Among these
135 rivers, Buriganga, Shitalakhya, Turag, Dhaleshwari, Moyuri, Surma, Korotoa rivers have
136 different types of industries located on their banks or in surrounding areas. Halda flows through
137 areas where tea gardening is prevalent while Mathavanga flows through Chuadanga district that
138 is mostly agricultural economy dependent. Brahmaputra flows through an urban unindustrialized
139 residential area, Mymensingh district. The map in Figure 1 was drawn using ArcGIS 10.3 (ESRI,
140 Redlands, CA).



141

142 **Figure 1:** Map of Bangladesh showing the ten selected rivers and corresponding monitoring

143 stations

144 Water quality reports published by the DOE from 2010 till 2016 (the latest published report)
145 were extracted for analysis of DO and BOD trend for seven years (2010 – 2016) and WQI
146 calculation using DO, BOD, pH, and SS [21,22,23,24,25]. Among the four parameters used for
147 WQI calculation, DO and BOD trend over the years was analyzed for the ten selected rivers as
148 pH was found to be near the neutral range and SS data was not available for all rivers across the
149 observed time period. Moreover, DO and BOD can be a good indicator of pollution in the rivers.
150 The amount of oxygen available in water for aquatic uptake is DO and if it drops between 2 – 4
151 mg/L, fishes get distressed in a hypoxic condition [26]. BOD is an indirect measurement of the
152 organic matters present in water which is quantified by tracking DO depletion needed for
153 degradation of the organic matters [27]. Therefore, there is a DO depletion in a water sample
154 with high BOD concentration; typically, BOD greater than 15 mg/L indicates a very polluted
155 water unsustainable for healthy aquatic environment. In a limited data acquisition situation, DO
156 and BOD can be very helpful for determining water quality of a waterbody. Therefore, DO and
157 BOD was calculated for all ten rivers from 2010 – 2016 using the data extracted for DOE
158 reports.

159 In addition to DO and BOD, two other parameters, i.e. pH and SS were considered for WQI
160 calculation. For aquatic sustainability, pH ranging from 6 – 9 is sufficient and a sudden change in
161 pH of a water indicates introduction of foreign matters into the waterbody [28]. The amount of
162 insoluble matters is quantified as SS which might be an indicator of a number of aquatic events,
163 i.e. runoff of particulate organics, algal bloom etc. WQI was calculated using a weighted average
164 of four parameters, i.e. DO, BOD, suspended solids (SS), and pH. Weights were employed on
165 DO, BOD, SS, and pH according to their values and an average of the assigned weighted values
166 were calculated for quantifying the water quality of the rivers as WQI [Equation 1].

167
$$WQI = \frac{1}{n} \sum_{i=1}^n I_i$$
 [Equation 1]

168 where, n = the number of parameters monitored, and I is the weight normalized value assigned to
 169 the monitored parameters.

170 The weights assigned to the parameters for WQI calculation was conducted following weight
 171 assignment proposed by Liou et al. (2004) [28]. Table 1 lists the weight assignment to the
 172 parameters used in this study for WQI calculation.

173 **Table 1:** Weight assignment on the parameters (pH, dissolved oxygen, biochemical oxygen
 174 demand, suspended solids) used for water quality index (WQI) calculation

Parameter weight		Parameters for WQI calculation			
Qualitative interpretation	Quantitative weight	pH	DO (mg/L)	BOD (mg/L)	SS (mg/L)
Good	1	6.5 – 8.5	> 6.5	< 3	< 20
Slightly polluted	3	4.6 – 6.4, 8.6 – 10.4	4.6 – 6.4	3 – 4.9	20 – 49
Moderately polluted	6	2 – 4.5, 10.5 – 12	2 – 4.5	5 – 15	50 – 100
Very polluted	10	< 2, > 12	< 2	> 15	> 100

175

176 A qualitative interpretation of the WQI was made according to Table 2.

177 **Table 2:** Qualitative interpretation of water quality index (WQI) assigned to the rivers

Water quality index (WQI)	Quantitative interpretation
< 2	Good
2 – 2.9	Slightly polluted
3 – 4.9	Moderately polluted
≥ 5	Very polluted

178

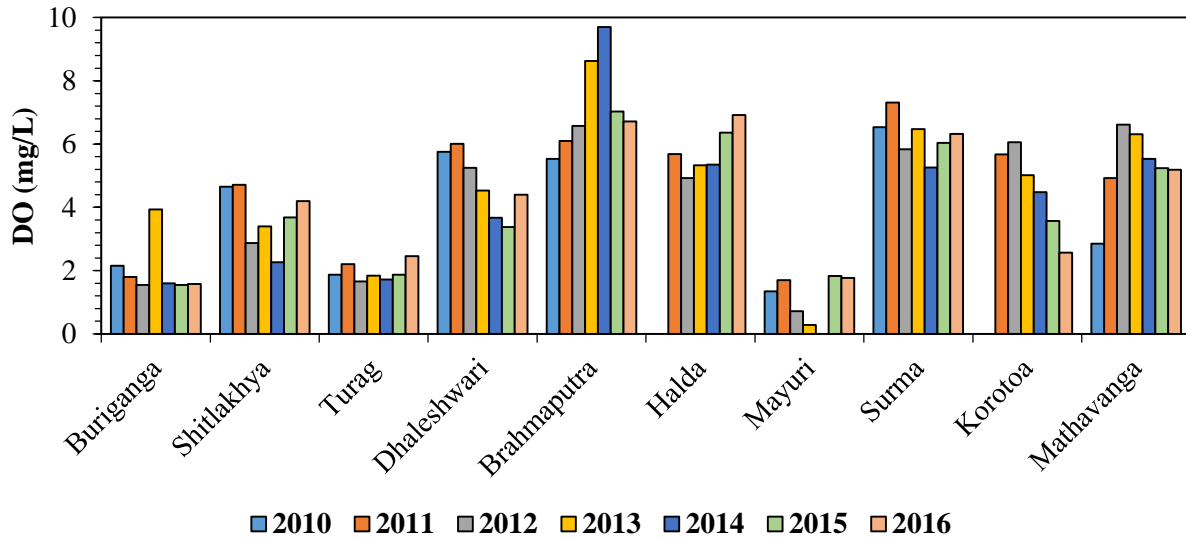
179 In addition to the assigned weights and WQI calculation, regression analysis of the data points
 180 across seven years were performed to analyze correlation of WQI with DO or BOD or both to

181 help predict water quality of rivers in resource-limited situations where only DO or BOD
182 parameters are available for monitoring. The regression analysis was performed using the
183 Analysis ToolPak add-on provided with Microsoft Excel.

184 **3. Results & Discussion**

185 **3.1. Dissolved oxygen (DO) level in ten selected rivers**

186 The amount of gaseous form of oxygen (O_2) dissolved in the water is measured as DO which
187 indicates the availability of oxygen for aquatic uptake. DO is therefore crucial for all forms of
188 aquatic lives [29]. By the direct absorption of O_2 from the atmosphere, rapid movement of water
189 and byproduct of photosynthetic activities atmospheric oxygen enters water. A number of factors
190 including temperature, salinity, presence of organic matter can affect DO level in water. The DO
191 levels in the ten selected rivers were extracted from the DOE reports and then annual average
192 was calculated to analyze trends of DO change 2010-2016 for all ten rivers as presented in
193 Figure 2.



194

195 **Figure 2:** Level of dissolved oxygen (DO) in ten rivers of Bangladesh across a time period of
 196 seven years starting from 2010 till 2016.

197 Three rivers, Buriganga, Turag and Mayuri had overall the lowest DO for the seven years of
 198 period. Except for 2013, DO level was near or below 2 mg/L (1.575 – 2.150 mg/L) in Buriganga
 199 in all other years. Similarly, DO of Turag was in the range of 1.66 – 2.455 mg/L all through the
 200 seven years. The extremely hypoxic conditions in Buriganga and Turag might have been caused
 201 by industrial pollution as both these rivers are located in the heavily industrialized areas of
 202 Bangladesh [5,18]. The surrounding areas of Buriganga is a hotspot for the tannery industry
 203 while many textile industries are located on or near the banks of Turag. Mayuri had 0.280 –
 204 1.675 mg/L DO in all through the seven years. Apart from industrial pollution, another reason for
 205 low level of DO in Mayuri can be relatively higher salinity in Mayuri as the river is very closely
 206 located near the Bay of Bengal.

207 Shitalakhya, Dhaleshwari, and Korotoa had DO level near 4 mg/L in the recent reported years,
 208 showing an overall downward trend. Shitalakhya river water sampling locations were near two of
 209 biggest factories in the country, Advanced Chemical Industries (ACI) Factory and Ghorashal

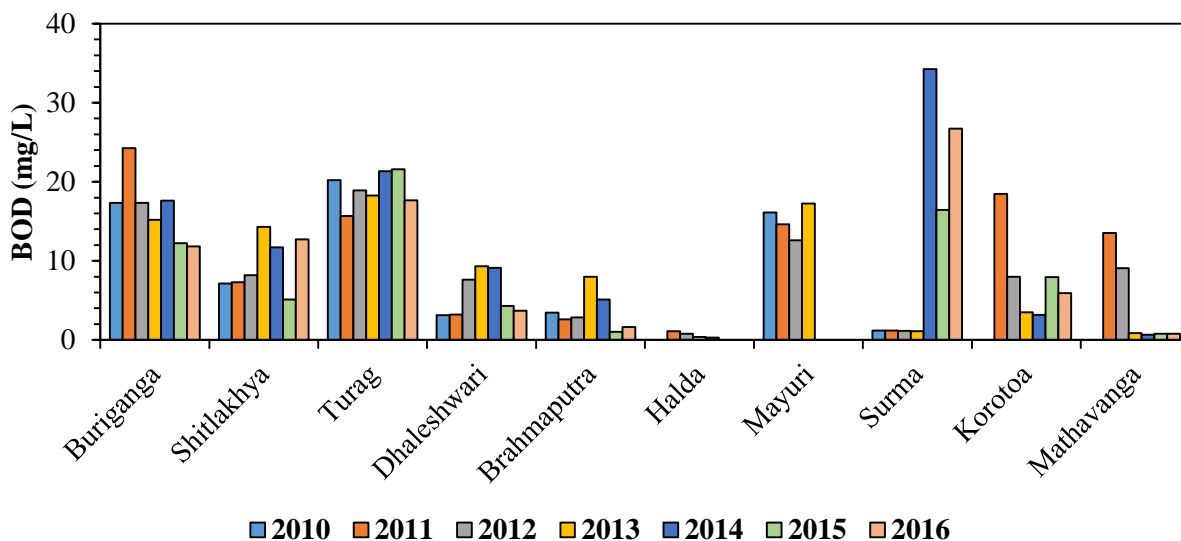
210 Fertilizer Factory. Dhaleshwari river water sampling stations were in Munshiganj and
211 Hemayetpur surrounded by manufacturing and textile industries. Korotoa river sampling
212 locations were in Bogura district where economy is heavily agriculture dependent with some
213 minor industries in the area. While DO level of Shitalakhya and Dhaleshway rivers were above 4
214 mg/L in 2016, it showed an ever-decreasing trend for Korotoa river reaching 2.565 mg/L in
215 2016.

216 Brahmaputra, Halda, and Surma had near 6.5 mg/L DO in recent reported years while
217 Mathavanga shows a downward trend for DO starting from 2012, the only year it had DO greater
218 than 6.5 mg/L. Mathavanga river sampling locations were in Chuadanga, an agriculture
219 dependent district. Brahmaputra and Halda sampling locations were in unindustrialized areas
220 where sampling locations of Surma were near a few manufacturing industries including Chhatak
221 Cement Factory. Level of DO in Brahmaputra was above 6.5 mg/L in 2012, 2013 and then
222 decreased in the next few years. Surma's DO level stayed at the same level ranging from 6.04 –
223 7.315 mg/L across the seven reported years while Halda's DO level showed an upward trend,
224 reaching 6.915 mg/L in 2016. Overall, location and surrounding industrialization level might be
225 an important factor leading to low DO in industrialized and high DO in relatively less
226 industrialized areas.

227 **3.2. Biochemical oxygen demand (BOD) in ten selected rivers**

228 Biochemical oxygen demand (BOD) is generally an indicator of presence of organic matter.
229 With a high level of organic matter present in water, consumption of DO for breaking down
230 organic matter causes DO depletion in water. Consequently, aquatic systems with high level of
231 BOD generally has low level of DO in the system. Accordingly, it was observed that BOD was
232 generally high in the rivers with low level of DO. Figure 2 shows the annual average BOD

233 calculated from the data extracted from DOE reports published from 2010 till 2016. DO was
 234 very low in Buriganga, Turag, Moyuri and these three rivers had BOD always in the toxic regime
 235 across the observed time period [Figure 3]. Buriganga river's BOD level dropped from 17.6
 236 mg/L in 2014 to 11.8 mg/L in 2016, but it was still toxic for aquatic healthy environment.
 237 Similarly, Turag and Mayuri rivers' BOD level was in the range of 18.9 – 21.6 mg/L and 12.6 –
 238 17.3 mg/L, respectively. Notably, the BOD level in Mayuri river was not available from 2014
 239 through 2016. However, low level of DO in Mayuri's water in 2015 (1.830 mg/L) and 2016
 240 (1.765 mg/L) is likely an indicator of a toxic level of BOD in the river in 2015 and 2016.



241
 242 **Figure 3:** Level of biochemical oxygen demand (BOD) in ten rivers of Bangladesh across a time
 243 period of seven years starting from 2010 till 2016.

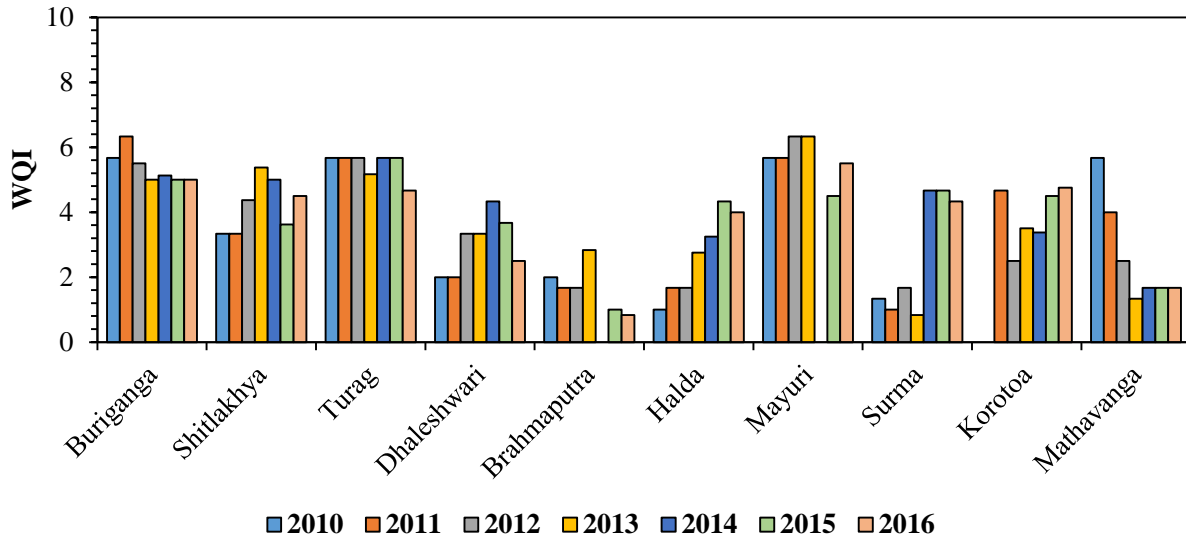
244 Brahmaputra, Halda, Mathavanga rivers showed a downward trend for BOD likely because of
 245 the less of an industrialization in the locations the rivers are located; especially, Mathavanga
 246 rivers' BOD level were in the healthy range of BOD (< 3 mg/L) in recent years. Notably,
 247 Halda's BOD levels in the most recent years were not available, but referring to the relatively
 248 high level of DO in Halda and the overall trend of DO And BOD in the river, it can be presumed

249 that Halda's BOD was still within the healthy range in 2014, 2015, and 2016. Korotoa's BOD
250 indicates moderate pollution (< 8 mg/L) but its BOD level stayed almost at the same level after
251 2010 indicating the pollution level in the river likely did not deteriorate further till 2016.

252 Dhaleshwari, Shitalakhya, and Surma rivers' BOD level was above the range for healthy level (>
253 3 mg/L). The level of BOD in Surma was in the range of 16.4 – 34.2 mg/L in recent years while
254 Dhaleshwari's BOD was below 8 mg/L indicating a moderate pollution level in Dhaleshwari
255 based on the recent BOD level in the river. The BOD level was above the healthy range in recent
256 years in Shitalakhya with the exception in 2015 (5.1 mg/L).

257 **3.3. Water Quality index (WQI) in ten selected rivers**

258 Water quality index (WQI) can indicate the overall quality of water. In absence of a universal
259 indexing of water quality different water quality agencies adopt different methods for WQI
260 assignment. In this study, DO, BOD, pH, and SS- these four parameters were considered for
261 WQI calculation. However, SS data was not available for all rivers. But weights were assigned to
262 each parameter according to the associated intensity and then an average of the total weight was
263 used for WQI employment to minimize the effect of lack of one or two parameters (if any). The
264 level of DO and BOD in all ten rivers across a seven-year period was discussed in the previous
265 sections. A separate section on pH level in the rivers was not provided as pH was within the
266 range of 6.5 – 8.5 in all the rivers which is a normal pH level for surface water [30]. Moreover,
267 no drastic fluctuation of pH was observed in the rivers. Additionally, SS values were also
268 considered for WQI calculation, when available. Figure 4 shows the calculated WQI for all ten
269 rivers in a seven-year period (2010 – 2016).



270

271 **Figure 4:** Calculated water quality index (WQI) for ten rivers from 2010 till 2016.

272 Among the ten rivers, Brahmaputra had the lowest WQI in recent years with a downward trend
 273 over the years while Halda showed an upward trend in WQI. As discussed earlier, Brahmaputra
 274 flows through a residential urban area that is not industrialized. Halda flows through hilly areas
 275 with tea gardens. One possible reason for Halda’s increasing WQI over the years could be due to
 276 run-off from tea gardens that would carry sediments, nutrients with it. Buriganga, Turag, and
 277 Mayuri are the three most polluted rivers in terms of WQI across the observed time period,
 278 showing no major fluctuations over the years. Buriganga, Turag, and Moyuri are in the most
 279 industrialized areas of Bangladesh where some of the industries include tanneries, textiles, and
 280 manufacturing industries. Lack of regulatory enforcement and infrastructure for industrial
 281 discharge control very likely contributed to the high level of WQI in those three rivers.
 282 Contribution of industrial discharge can be more clearly observed by comparing WQI of these
 283 three rivers to that of Brahmaputra and Mathavanga. Being in relatively under-industrialized
 284 areas, Brahmaputra and Mathavanga had lower WQI compared to Buriganga, Turag, and
 285 Moyuri.

286 Shitalakhya (4.5 – 5.0), Surma (4.3 – 4.7), and Korotoa (4.5 – 4.8) rivers had WQI almost at the
 287 same level in recent years (2014 – 2016) indicating moderate pollution in the rivers. Pollution in
 288 Shitalakhya and Surma rivers might be because these rivers are adjacent to some of the largest
 289 factories in the country, i.e. ACI, Chhatak cement factory. Korotoa’s moderate pollution might
 290 have been caused by the small industries located in the adjacent area. Dhaleshwari river showed
 291 a downward trend of WQI from 4.3 in 2014 to 2.1 in 2016. However, Dhaleshwari river is
 292 located in an area with manufacturing and textile industries. There is no evidence or
 293 documentation of any drastic regulatory enforcement in the area for controlling industrial
 294 discharge. The downward trend of WQI in the river might be due to lack of sampling in the
 295 monitoring stations which is a very common phenomena in many of the monitoring stations
 296 across the country. Overall, Brahmaputra and Mathavanga were the only two rivers with a WQI
 297 for healthy aquatic environment identified in this study. All the other rivers were either slightly
 298 or moderately polluted and not healthy for aquatic lives. The degree of pollution in the ten rivers
 299 in 2016 based on WQI was in the order of Mayuri > Buriganga > Korotoa > Turag > Shitalakhya
 300 > Surma > Halda > Dhaleshwari > Mathavanga > Brahmaputra. A qualitative interpretation was
 301 made based on the WQI calculated in this study for a convenient identification of the polluted
 302 rivers [Table 3].

303

304 **Table 3:** Degree of pollution in the ten selected rivers presented with different color codes

Color code:

	Good
	Slightly polluted
	Moderately polluted
	Very polluted

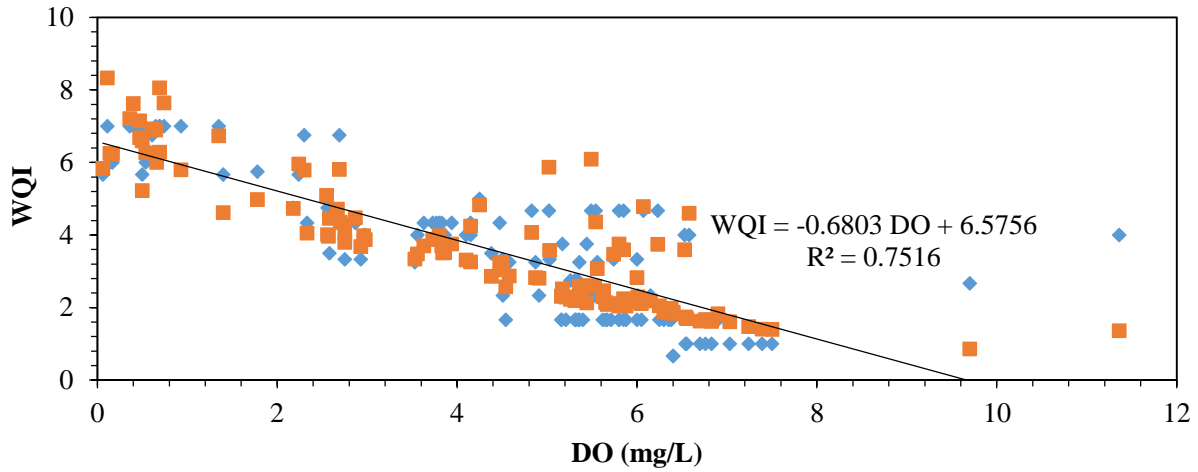
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River	2010	2011	2012	2013	2014	2015	2016
Buriganga	Orange	Dark Orange	Orange	Orange	Orange	Orange	Orange
Shitalakhya	Orange	Orange	Orange	Orange	Orange	Orange	Orange
Turag	Orange	Orange	Orange	Orange	Orange	Orange	Orange
Dhaleshwari	Yellow	Yellow	Orange	Orange	Orange	Orange	Yellow
Brahmaputra	Yellow	Green	Green	Yellow	White	Green	Green
Halda	Green	Green	Green	Yellow	Orange	Orange	Orange
Mayuri	Orange	Orange	Dark Orange	Dark Orange	White	Orange	Orange
Surma	Green	Green	Green	Green	Orange	Orange	Orange
Korotoa	White	Orange	Yellow	Orange	Orange	Orange	Orange
Mathavanga	Orange	Orange	Yellow	Green	Green	Green	Green

306

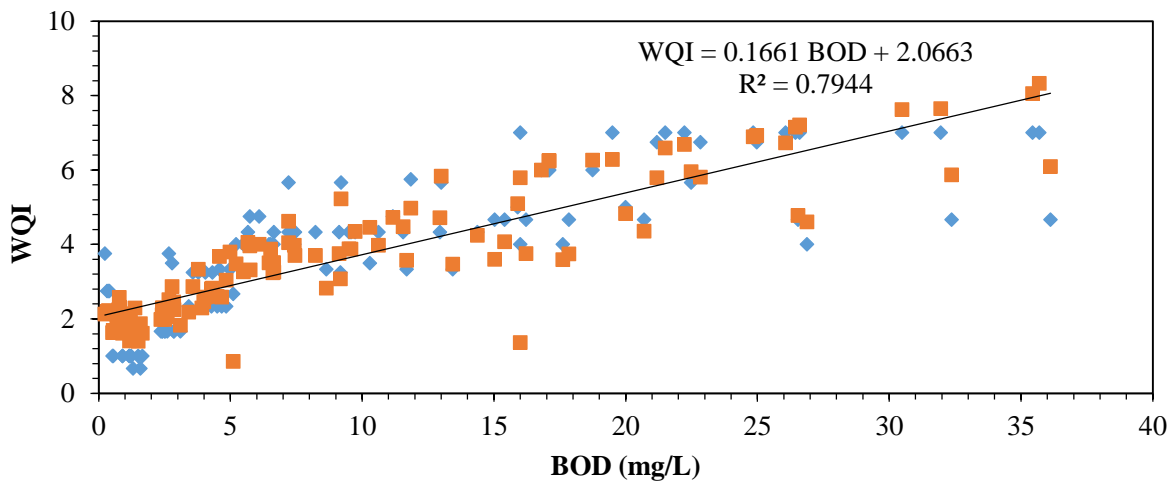
307 As presented in Table 3, Buriganga, Shitalakhya, Turag, Halda, Mayuri, Surma, Korotoa rivers
308 were moderately polluted in 2016, and Dhaleshwari was slightly polluted while Brahmaputra and
309 Mathavanga were in good conditions. This shows a trend of rivers being more polluted when
310 there are industries in surrounding areas which coincides observations made by other reports
311 [5,16,17,18,19,20].

312 Monitoring of more parameters and incorporation of them into WQI will be helpful for
313 calculation of more accurate WQI representative of the actual water quality. However,
314 monitoring of more parameters might be challenging due to lack of resources and infrastructure
315 in developing countries like Bangladesh. Therefore, WQI prediction with a few parameters will
316 be helpful in resource limited situations. Hence, a correlation between DO, BOD and WQI was
317 analyzed in this study [Figure 5].



(a) ◆ Actual WQI ■ Predicted WQI — Fitted Predicted WQI

318



(b) ◆ Actual WQI ■ Predicted WQI — Fitted Predicted WQI

319

320 **Figure 5:** Regression analysis of (a) dissolved oxygen (DO) and water quality index (WQI), and

321 (b) biochemical oxygen demand (BOD) and WQI to determine correlation between them.

322 Predicted WQI using DO and BOD as variable resulted in R^2 of 75.16% and 79.44%,

323 respectively.

324 With using DO and BOD both as variables, WQI can be predicted as follows ($R^2 = 86.68%$ and

325 standard error = 0.68)

326 $WQI = 4.42 - 0.42 DO + 0.11 BOD$ [Equation 2]

327 In challenging situations with difficulty in monitoring multiples parameters, the correlation of
328 WQI with DO and BOD individually or both parameters can be helpful for prediction of water
329 quality. Notably, BOD levels for some rivers in some years were not available (Halda and
330 Moyuri: 2014 – 2016; Korotoa: 2013). In the correlation analysis, those data points were hence
331 not considered.

332 **4. Conclusion**

333 Access to clean water is essential for all living beings. Similarly, clean and pollution free surface
334 water is crucial for a healthy aquatic environment where all aquatic beings can sustainably
335 thrive. However, with an increasing industrial and agricultural production to meet the demand of
336 the ever-increasing population, water pollution is becoming challenging for sustainable
337 development. This phenomenon is particularly more challenging in developing countries like
338 Bangladesh where lack of infrastructure and regulatory enforcement pose higher risk for water
339 pollution. Anthropogenic activities generated huge transformations in the river water quality and
340 ecosystem in the country. Because of economic benefit many industries are established near the
341 river side and the subsequent discharge of untreated and semi treated toxic waste into the river is
342 likely to negatively affect the water quality in the receiving waterbodies.

343 The water quality index can be helpful for reducing the bulk of the monitored parameters into a
344 single value to communicate in a rearranged and consistent manner. Hence, a well-adopted water
345 quality indexing system can be helpful for remediation planning and implementation purposes.
346 However, currently the country does not have a country wide indexing system in place. There are
347 a few published works on assignment of WQI on some selected waterbodies. But an overall

348 indexing to apply on a vast region of the country covering both industrialized and under-
349 industrialized areas is yet to be explored. This study proposed an indexing system considering
350 four parameters (DO, BOD, pH, and SS) generally monitored in the monitoring stations of DOE.
351 An analysis of DO, BOD, and WQI in the ten selected rivers showed that rivers located in the
352 heavily industrialized areas were highly polluted and the degree of pollution were generally
353 lower in the areas with fewer industries. Rivers in the industrialized areas showed a general trend
354 of having low DO and high BOD. The rivers can be in the order of Mayuri > Buriganga >
355 Korotoa > Turag > Shitalakhya > Surma > Halda > Dhaleshwari > Mathavanga > Brahmaputra
356 in terms of the degree of pollution based on the WQI assignment in this study. This order can be
357 helpful for identifying which rivers need remediation on a preferential basis.

358 Similarly, WQI can be calculated for other rivers in the country to gather a better understanding
359 of the degree of pollution in the rivers and make a holistic plan for remediation of the rivers.
360 However, setting up more monitoring stations in the rivers and frequent sampling is crucial for
361 assignment of WQI for development and implementation of remediation plans. In a resource
362 limited situation where only one or two parameters are available for monitoring, a simplified
363 WQI formula can be helpful. The relationship derived in this study can be useful for prediction
364 of WQI using DO, BOD or both parameters.

365 **Author Contributions**

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369 Original draft, Writing – Review & Editing. **Tahsin, A.:** Data Curation, Writing – Review &

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371 Investigation, Data Curation, Writing – Original draft, Writing – Review & Editing, Supervision.

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374 **Conflicts of Interest**

375 The authors declare no conflict of interest.

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