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Physicochemical assessment of Dhanmondi lake water in Dhaka city, Bangladesh

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ABSTRACT

The main objective of this study was to examine the quality of water in the large reservoir of the Dhaka city lake and to determine whether it would be economically acceptable to purify this water for later use and to make it usable. The water quality parameters investigated are pH, temperature, electrical conductivity, hardness, alkalinity, total dissolved solids, total suspended solids, chloride, sulfate, phosphate, nitrite, nitrate, biochemical oxygen demand, chemical oxygen demand, and dissolved oxygen. The study has been done targeting three specific locations on Dhanmondi Lake, where crowds are comparatively the highest. This implies that there is a significant likelihood of pollution as well. The results of our 13-month study show that the quality of Dhanmondi lake water is somewhat higher than the international standard and some is at a tolerable level determined by the Bangladesh Department of Environment.

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1. Introduction

Lakes originate as a product of geological processes and terminate as a result of the loss of the ponding mechanism, by evaporation caused by changes in the hydrological balance, or by infilling caused by sedimentation. The mechanisms of origin are numerous and are reviewed by [1], who differentiated 11 major lake types, subdivided into 76 subtypes. According to preliminary data from the sixth census of South Asian countries published on 27 July 2022 (Population and Housing Census 2022), Bangladesh now has a population of 165,158,616 in 2022 which was 144,043,697 in 2021. This report shows that 83.35 million women and 81.71 million men. More than 44 million people live in the Dhaka Division, including 13 districts [2]. The World Bank says Dhaka, with its current population of 15 million people, bears the distinction of being the fastest growing in the world. Between 1990 and 2005, the city doubled in size - from 6 to 12 million. By 2025, the U.N. predicts Dhaka will be home to more than 20 million people larger than Mexico City, Beijing, or Shanghai [3].

The metropolis of Dhaka has polluted drains, lakes, and rivers. Although water is an inevitable component of natural resources and plays an important role in many purposes, such as drinking, irrigation, aquaculture and livestock use, the city of Dhaka people pollute it by adding different types of pollutants to its adjacent drains. The quality of water is deteriorating day by day due to many of the biological, physical, and chemical variables that cause water toxicity [4]. In Dhaka city, there are four major lakes which are, Dhanmondi Lake, Ramna Lake, Gulshan Lake (Gudara Ghat) and Crescent Lake [5]. In addition to this, Dhaka had over 50 canals surrounded by four rivers, Buriganga, Balu, Turag and Sitalakshya [6]. The main objective of the study was to evaluate the quality of water (pH, temperature, electrical conductivity, hardness, alkalinity, total dissolved solids, total suspended solids, chloride, sulfate, phosphate, nitrite, nitrate, BOD, COD and dissolved oxygen) in the sizable reservoir of the Dhaka City Lake, located in the Dhanmondi zone, and to determine whether it would be economically feasible to purify this water.

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Table 1. Sampling coordination.

Sampling site	Geographic coordinate system coordinates	
	Latitude	Longitude
S1	23°44'46.95"N	90°22'39.64"E
S2	23°44'42.91"N	90°22'42.59"E
S3	23°44'43.34"N	90°22'40.48"E

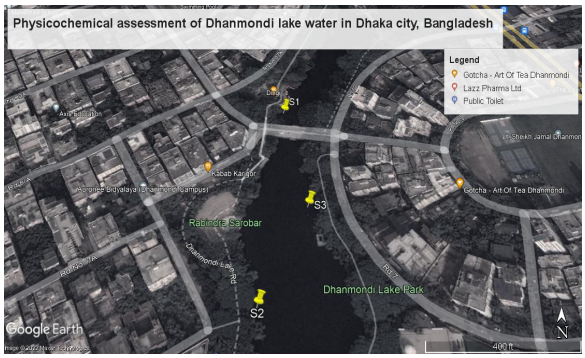

Figure 1. Sampling locations.

The study was carried out during the 13-month duration of the project at three locations on Dhanmondi Lake, where the crowds are comparatively dense.

2. Experimental

2.1. Selection of sampling site

The present investigation was conducted over a period of 13 months from July 2020 to July 2021 in the study area of Dhanmondi Lake in Dhaka. The sampling and physical tests were performed during the study period. Surface lake water sampling was carried out following the method described by Kevin Simmons in Region 4, US Environmental Protection Agency, Laboratory Services and Applied Science Division Athens, Georgia [7]. Sampling coordination is given in Table 1 and Figure 1.

2.2. Sampling method

Water resource management includes checking the quality of the water. Every sample that is obtained needs to be an accurate depiction of the region being sampled. Depending on how accurately the samples were taken, laboratory analysis results may or may not be beneficial. Thus, it is advised to only gather a limited number of samples. Surface lake water sampling was carried out following the method described by Kevin Simmons in Region 4, US Environmental Protection Agency, Laboratory Services and Applied Science Division Athens, Georgia [7]. There are two types of water sampling strategies regarding the time frame when the samples are collected, one is discrete samples, and the other is composite samples. Discrete sample, also known as grab sample, is a single sample collected in an individual container [8]. Grab sampling was chosen for this study.

2.3. Testing methodology and meteorological data collection

Water temperature: The water temperature was taken using a mercury thermometer with a range of -5.0 to 100.0 °C at the time of sampling. Mercury thermometer is used for repeated measurements along the depth of water [9].

pH (Potent hydrogen): The pH of surface water was determined by the APHA 1995 standard method with a portable combo meter (Model Hanna, HI 98130, USA) [10].

Electrical conductivity (EC): Electrical conductivity value of surface water was determined by the APHA 1995 standard method with portable combo meter (Model Hanna, HI 98130, USA) [10,11].

Total dissolved solids (TDS): The total dissolved solids value of water was determined by ion electrode technique using APHA 1995 standard method with portable combo meter (Model Hanna, HI 98130, USA) [10,11].

Hardness: Total hardness was measured by colorimetric titration with an EDTA solution followed by the EDTA titrimetric method (hardness) [12]. The hardness level as mg/L (ppm) calcium carbonate is determined by an EDTA (Ethylene-diamine-tetra acetic acid) titration.

Chloride: The chloride level was determined by silver nitrate titration, using potassium chromate as an indicator (Mohr's method) [13].

Total suspended solids (TSS): Total suspended solids of surface water were measured followed by standard methods (2005), 2540D and EPA (1983) method 160.2 [14].

Dissolved oxygen (DO): Oxygen content in water was measured as dissolved oxygen (DO). The dissolved oxygen value of the water samples was measured using the Lutron 5509 DO meter with a polarographic probe with built-in temperature sensor [15,16].

Biochemical Oxygen Demand (BOD): Biochemical oxygen demand was measured by five days of incubation using the ion selective method [17].

Chemical Oxygen Demand (COD): Chemical oxygen demand was determined by the USEPA 410.4 (U.S. Environmental Protection Agency) approved method for the determination of chemical oxygen demand in surface waters and wastewater. Oxidizable organic compounds reduce the dichromate ion (orange) to the chromic ion (green). The amount of chromic ions formed was determined by photometric analysis in a multiparameter bench photometer (Hanna HI 83099) [18].

Alkalinity: The reaction causes a distinctive range of colors from yellow to green to greenish blue to develop and is measured by the colorimetric method on a multiparameter bench photometer (Hanna HI 83099) [18]. The light source is a tungsten lamp with a narrow band interference filter @ 575 nm.

Sulfate: Sulfate was measured using the ferrous sulfate method in a multiparameter bench photometer (Hanna HI 83099) [18]. The reaction between nitrite and the reagent causes a greenish-brown tint in the sample. The light source is a tungsten lamp with a narrow band interference filter @ 575 nm.

Table 2. Comparisons of lake water data with that of surface water standard according to ECR 1997 and other founded studied data.

Parameters	Minimum	Maximum	Average data±SE (Current study)	Standard *	Absolute correlation with temperature (°C)	Previously studied data	References
Temperature (°C)	26.1	26.9	26.6±0.08	-	-	26.44	[19]
Hardness (ppm)	63.0	69.0	64.8±0.50	-	0.49	93.88	[19]
pH	7.08	7.21	7.14±0.01	6.5-8.5	0.77	7.88	[19]
EC (µS/cm)	580.0	590.0	581.5±1.04	-	0.07	417.44	[19]
TDS (ppm)	290.0	290.0	290.0±0.00	-	-	201.65	[19]
Cl^- (ppm)	21.0	35.0	27.5±1.25	-	0.28	21.95	[20]
DO (mg/L)	5.1	5.7	5.4±0.06	5 or more	0.23	5.8	[20]
BOD (mg/L)	8.0	9.0	8.5±0.08	6 or less	0.82	12.4	[20]
COD (mg/L)	20.0	31.0	24.1±0.77	-	0.06	35.75	[20]
Alkalinity (mg/L)	80.0	90.0	85.0±0.99	-	0.02	72.25	[20]
TSS (mg/L)	167.0	187.0	175.5±1.73	-	0.26	-	-
SO_4^{2-} (mg/L)	12.0	20.0	16.1±0.59	-	0.33	-	-
PO_4^{2-} (mg/L)	2.1	3.7	2.8±0.12	-	0.31	-	-
Nitrite (mg/L)	0.01	0.08	0.05±0.01	-	0.38	-	-
Nitrate (mg/L)	0.01	0.05	0.02±0.00	-	0.17	-	-

* Surface Water standard according to the Schedule-3(A) of Environmental Conservation Rules, 1997, Government of Bangladesh. Water usable by fisheries.

Table 3. Comparison of water quality parameters among Dhanmandi Lake, Ramna Lake, Crescent Lake, Hatirjheel Lake, and Gulshan Lake.

Parameters	Average data±SE (Current study)	Dhanmandi Lake	Ramna Lake	Crescent Lake	Hatirjheel Lake	Gulshan Lake
Temperature (°C)	26.6±0.08	26.44 [19]	22.54 [21]	24.59 [21]	24.24 [21]	-
Hardness (ppm)	64.8±0.50	93.88 [19]	95.0 [21]	108.56 [21]	105.1 [21]	222 [22]
pH	7.14±0.01	7.88 [19]	7.73 [21]	7.85 [21]	7.67 [21]	6.70 [22]
EC (µS/cm)	581.5±1.04	417.44 [19]	154 [21]	282 [21]	618.2 [21]	305 [20]
TDS (ppm)	290.0±0.00	201.65 [19]	85.3 [21]	112.87 [20]	339.9 [21]	414.3 [22]
Cl^- (ppm)	27.5±1.25	21.25 [20]	-	10.22 [20]	29.7 [20]	45.66 [22]
DO (mg/L)	5.4±0.06	5.8 [20]	3.51 [21]	3.92 [21]	2.68 [21]	6 [20]
BOD (mg/L)	8.5±0.08	12.4 [20]	0.93 [21]	0.73 [21]	3.15 [21]	10.2 [22]
TSS (mg/L)	175.5±1.73	14.5 [20]	-	20.25 [20]	44.5 [20]	52.33 [22]
Alkalinity (mg/L)	85.0±0.99	72.25 [20]	48.9 [21]	120.7 [21]	249.1 [21]	109.6 [22]
COD (mg/L)	24.1±0.77	35.75 [20]	-	57 [21]	51.25 [20]	63.33 [22]

Phosphate: Phosphate was measured using standard methods for the examination of water and wastewater, 18th edition, amino acid method using a multiparameter bench photometer (Hanna HI 83099) [18]. The reaction between phosphate and reagents causes a blue tint in the sample. The light source is a tungsten lamp with a narrow band interference filter @ 525 nm.

Nitrite: Nitrite was measured by adapting the diazotization method 354.1 of the Environmental Protection Agency (EPA) on a multiparameter bench photometer (Hanna HI 83099) [18]. The reaction between nitrite and the reagent causes a pink tint in the sample. The light source is a tungsten lamp with a narrow band interference filter @ 525 nm.

Nitrate: Nitrate was measured by adaptation of the cadmium reduction method in a multiparameter bench photometer (Hanna HI 83099) [12]. The reaction between the nitrate and the reagent causes an amber tint in the sample. The light source is a tungsten lamp with a narrow band interference filter @ 525 nm

3. Results and discussion

The temperature value varies with the change of ambient condition. The average current data studied is compared with previously studied data and the standard value given by the Environmental Conventional Rules 1997 (Table 2). Where shown that the average value of pH found from lake water samples was 7.14, which was slightly alkaline in nature. The average value of EC found from lake water samples was 582 µS/cm means that the lake water contains higher concentration of ions. The average value of TDS found in lake water samples was 290 ppm, which means that the lake water contains a dissolved salt content. The average hardness value found from lake water samples was 64.8 ppm which means that lake water contains multivalent elements. The average value of chloride found in lake water samples was 28 ppm, which is indicating that the lake water contaminated chlorinated materials. The average value of total suspended solid found from lake water samples was 176 mg/L means that the lake water is most likely turbid. The average value of dissolved oxygen found in lake water samples was 5.4 mg/L, which was within the standard value given by the DoE means, which was likely suitable for fisheries, but the average value of the biological oxygen demand found in lake water samples was 8.5 mg/L, which was above the standard value given by the DoE means, which is not suitable for fisheries. Where the average value of chemical oxygen demand found in lake water samples was 24 mg/L, which is proof that the water was polluted somehow. The average value of alkalinity found from lake water samples was 85 mg/L, proof that the water was alkaline in nature as which support the average pH value of the tested sample. The average value of sulfate, phosphate, nitrite and nitrite found in lake water samples was 16, 2.8, 0.05, and 0.02 mg/L, respectively. The findings of our study indicate that the water quality of the Dhanmondi Lake is somewhat higher than that of the standard values and that some of it is at a level that has been deemed bearable by Bangladesh's Department of Environment. The wide territory surrounding the lake makes it more probable that the water will be easily contaminated. Therefore, the current study demonstrates that some fundamental quality measure parameters cannot satisfy the standard set by the Environment Conservation Rules of the Government of Bangladesh due to the presence of pollutants in the lake water.

Comparing the findings of this study with other studies on other lakes in the city (Table 3), we get a mixed-up scenario. The hardness of this lake is comparable to that of Dhanmondi Lake and is comparatively lower than other lakes [19]. Similar is the case with TDS [19,20]. However, the water contains far more suspended solids than other water bodies, as suggested by the high TSS, with a standard deviation of 100.837. We get a notion that this lake is less polluted comparatively, because of lower COD than other lakes [20-22], having a standard deviation of 17.67. Additionally, a comparatively lower BOD (with st. dev = 16.07) suggests that the lake suffers a lesser disposal of sewage and septic waste, compared to the other lakes, and compared to the previous study (Table 3), it appears that the situation is now better. The higher concentration of chloride and higher electrical conductivity suggest that the inorganic solutes are

plentiful, which should be noted with alarm. However, the DO is more or less similar, which is a good sign.

In Table 3, a demonstration of surface water quality for four main lakes in the city of Dhaka has shown where the variation of water quality throughout the year against the average water temperature shows a weak correlation Table 2, which supports the findings of previous studies [23,24]. The correlation was found to be more or less similar. From this insignificant value of R, it can be concluded that the natural effect of seasonal variation is minimal, therefore any significant difference between months is an effect of human pollutions or may be the seasonal variations of human consumption and pollution is reflected here. In addition, the relations between pH and the other parameters were also found to be minimal (< 0.7 in absolute), which also supports the findings of other research [25], except BOD (r = 0.78), the reason behind which deserves further investigation.

4. Conclusions

Current study shows that due to presence of pollutants in the lake water some basic but quality measure parameters are not unable to meet the standard suggested by The Environment Conservation Rules by Bangladesh. Such as the biological oxygen demand was far higher than the standard value 6 or less mg/L and due to the presence of non-biodegradable materials in the lake of the study area, the chemical oxygen demand is also high. As the BOD value was found higher than the standard value, it was suggested the water was not suitable for fisheries as well as the cod value also found high. As the study shows, the values of pH, alkalinity, TDS, TSS, and hardness are high for the application and the drinking purpose of such type of water will involve so many industrial steps such as filtration, ion exchanging, pre-activated carbon filtration, reverse osmosis, post-activated carbon filtration, mineral dosing, ultra violet ray screening, *etc*. Which will not economically fusible that's why suggested not use lake water as a source of drinking water purification as raw water.

Due to the open space around the lake, the lake water is more likely to be easily polluted. The level of this pollution can be reduced through some measures such as (i) the appropriate implementation of local laws related to environmental protection; (ii) with the help of advanced technology, a regional water purification plant should be set up for wastewater treatment and polluted water and waste from factories, hospitals, municipalities and other institutional wastewater should be disinfected, treated, and discharged into lakes, rivers, and seas; (iii) increase public awareness and (iv) plant trees around the reservoir.

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Ethical approval: All ethical guidelines have been adhered.
Sample availability: Samples are available from the author.

CRediT authorship contribution statement

Conceptualization: Mohammed Khorshed Ali , Ahmed Jubaer; Methodology: Ahmed Jubaer, Mohammed Khorshed Ali; Software: Muhammad Tasneem Zafar, Mohammad Zahirul Islam Talukder; Validation: Ahmed Jubaer, Muhammad Tasneem Zafar; Formal Analysis: Ahmed Jubaer, Mohammad Zahirul Islam Talukder; Investigation: Mohammed Khorshed Ali, Mohammad Zahirul Islam Talukder; Resources: Mohammad Zahirul Islam Talukder, Ahmed Jubaer; Data Curation: Mohammed Khorshed Ali, Mohammad Zahirul Islam Talukder; Writing - Original Draft: Ahmed Jubaer, Mohammad Zahirul Islam Talukder; Writing - Review and Editing: Ahmed Jubaer, Mohammed Khorshed Ali; Visualization: Mohammed Khorshed Ali, Mohammad Zahirul Islam Talukder; Funding acquisition: Mohammad Zahirul Islam Talukder, Mohammed Khorshed Ali; Supervision: Mohammed Khorshed Ali, Mohammad Zahirul Islam Talukder; Project Administration: Mohammad Zahirul Islam Talukder, Mohammed Khorshed Ali.

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