Seasonal variation of water quality of three urban small lakes in West Java, Indonesia

Sulastri\textsuperscript{1,2} and Ira Akhdiana\textsuperscript{1}

\textsuperscript{1}Research Centre for Limnology, Research Organization for Earth Science, National Research and Innovation Agency of Republic Indonesia (BRIN), Cibinong 16911, West Java, Indonesia

\textsuperscript{2}Corresponding author: sulastri@limnologi.lipi.go.id

Abstract. Urban lakes play an important role in supporting quality of human life. There are more than 200 urban lakes in Jabodetabek areas, some of which are experiencing high risk of disappearance due to pollution, eutrophication, and sedimentation. There have been limited long monitoring of limnological data on appropriate management practice to protect the integrity of this vulnerable system. This aim of study is reveal seasonal variations of water quality in Lake Cibuntu, Lake Dora, and Lake Lotus in Cibinong, West Java to support the management strategy of lakes. Water quality data including water depth, conductivity, Total Dissolved Solid, pH, Dissolved Oxygen, nutrient, were collected biweekly from July 2018 to July 2019. This result revealed that Lake Cibuntu and Lake Lotus have high variability of water depth compared to Lake Dora with the range 31 to 120 cm, 32 to 84 cm and 72 to 113 cm. The dynamic of water depth seems having an effect to the water quality variability in observed lakes. In term of nutrient, it showed a different pattern of variability fluctuation between observed lakes. The pattern of seasonal variability of water quality appeared to be related with seasonal of the year and water source.

1. Introduction

Urban lakes are important freshwater resources to support the quality of human life by providing services such as water supply, recreation, and socio-economic importance. Lakes in urban area vulnerable to the water quality deterioration due to anthropogenic impact. Increasing anthropogenic activities in the catchment area influence in aquatic ecosystem and their surrounding area. The changes of natural catchment areas into urban area have contributed to a larger extent towards deterioration of water quality leading to accelerated eutrophication [1,2]. Previous study has shown the urban environment influence on the deterioration of water quality [3]. Water movement is responsible for transporting sediment, nutrients and pollutants from the catchment area to the lakes [4].

In west Java urban lake called “Situ” have many functions such as used for water supply, recreation, maintenance ground water table and flood control. Urban lakes also have important roles related to natural resources conservation since lakes are habitat for great of aquatic organism species and reserve the freshwater sources [5]. There are than 200 small urban lakes in West Java, particularly in area of Jakarta, Bogor, Depok, Tangerang dan Bekasi (Jabodetabek) with the surface area ranges from 1 to 160 ha and the average of water depth 0.5 to 2 m [6, 7]. Generally urban lakes have small size and volume which cause unstable hydrological balance and sensitive to the anthropogenic effect from the watershed such as pollution and eutrophication [8].
Urban lakes in Jabodetabek are the most threatened ecosystem due to land use change, sedimentation, eutrophication, and water pollution [9]. Eutrophication is among the most problems in this area. Water quality of urban lake has become a topic of concern due to the many diverse uses and the important healthy ecosystem for the city communities. Reliable scientific information is important for sustainable management of urban lakes. Water quality monitoring is important for assessing the value of waters for a healthy ecosystem, domestic water or recreation. Water quality monitoring is a tool, to recognize and verify on the pollution levels and related to the effectiveness of management plans. Hence monitoring of these water resources is a major key for sustainable management [10]. Temporal variation in water quality is related to climatic conditions, source of water, land use type, seasonal hydrology [11]. During the dry season, the eutrophication is one of most important hydrobiological process with have potential of deterioration of water quality. Seasonally of water quality are also related to the regional characteristic and condition of surrounding area of lake [12]. Every lake may be different of water quality due to different driving forces of water quality condition. [13, 14].

There are three urban small lakes in Cibinong, namely Situ Cibuntu, Situ Dora or Situ Cilalay and Situ Lotus which have a different morphological, hydrological characteristic [15]. Lake Dora receive the water coming from ground water while Lake Cibuntu and Lake Lotus receive water source which is coming from the streams flowing through agriculture and human settlement. Lake Cibuntu is used for domestic while Lake Dora and Lake Lotus for Tourism. In Lake Cibuntu, eutrophication often occurs after restoration by removing sediments. Reliable scientific information and sufficient data are essential to identify environmental factors driving the eutrophication in urban lake as Lake Cibuntu. This study is aimed to reveal seasonal variations of water quality in Lake Cibuntu, Lake Dora, and Lake Lotus in Cibinong.

2. Materials and methods
Research area is in Lake Cibuntu, Lake Dora and Lake Lotus located at Cibinong City, West Java Indonesia with the geographic position 106° 21' - 107° 13' East and 6° 19' - 6° 47' South (Figure 1). Climate type in Cibinong is considerably high rain rainfall particularly in December, January and February while lower rain fall was found in June, July and August (Figure 2) [16]. Lake Cibuntu, Lake Dora and Lake Lotus are small lakes with the area 2.11; 1.31; 078 ha and the maximum depth are 1.20; 1.13 and 0.84 m respectively. Lake Cibuntu and Lotus receive water from streams while water source in Lake Dora from ground water.

Water Samples for water quality data including total nitrogen (TN), total phosphorus (TP) water temperature, potential hydrogen (pH), Dissolved Oxygen (DO), and conductivity data total dissolved solid (TDS) were collected twice a week at three or four sampling points from July 2018 to July 2019. Water quality (temperature, DO, pH, conductivity and TDS) was measured using water quality checker (YSI) while TN and TP concentration were measured by using Brucine method and Ascorbic acid method respectively [17]. Water depth was examined by measurement of the Secchi depth
3. Result and discussion

Higher water depth was recorded in Lake Dora with the range and average of 70 to 113 cm and 94.53 cm respectively (Table 1). In Lake Dora, water depth fluctuation was more stable than Lake Cibuntu and Lake Lotus. Lake Cibuntu, Water depth showed a higher fluctuation compared to Lake Dora and Lake Lotus. Seasonally higher water depth in Lake Cibuntu was recorded rainy season (November and December 2018), while the lower water depth was recorded in dry season (July and August 2018) (Figure 3). In lake Lotus, higher water depth was recorded in December 2018 and July in 2018. The
lower water depth in Lake Cibuntu and Lake Lotus was recorded in dry season (August to September, 2018) and rainy season (January to February, 2019) (Figure 3).

Table 1. Range and average value the water physical-chemical properties of observed lakes

| Parameters          | Lakes          |          |          |
|---------------------|----------------|----------|----------|
|                     | Cibuntu        | Dora     | Lotus    |
| Depth (cm)          | range 31-120   | 70-113   | 32-84    |
|                     | average 61.77  | 94.53    | 47.94    |
| Temperature (°C)    | range 27.33-32.03 | 28.25-31.6 | 27.0-32.83 |
|                     | average 30.33  | 29.56    | 29.45    |
| DO (mgL⁻¹)          | range 5.59-9.95 | 2.83-7.41 | 3.98-8.95 |
|                     | average 7.305  | 5.54     | 6.22     |
| pH                  | range 5.98-7.16 | 5.23-6.53 | 6.2-7.19 |
|                     | average 6.69   | 5.92     | 6.63     |
| TDS (mgL⁻¹)         | range 21.4-45.83 | 24.0-43.88 | 31.0-68.67 |
|                     | average 33.37  | 36.75    | 53.4     |
| Conductivity (mS·cm⁻¹) | range 0.053-0.079 | 0.037-0.075 | 0.049-0.122 |
|                     | average 0.055  | 0.06     | 0.09     |
| TN (mgL⁻¹)          | range 0.293-1.486 | 0.324-1.201 | 0.520-1.147 |
|                     | average 0.765  | 0.627    | 0.835    |
| TP (mgL⁻¹)          | range 0.001-0.052 | 0.001-0.083 | 0.001-0.071 |
|                     | average 0.020  | 0.022    | 0.032    |

The average of water temperature showed a little variation among of observed lakes (Table 1). Seasonally, little variation of water temperature was related to daily water temperature variation (Figure 3). The Higher average value of DO concentration (73.05 mgL⁻¹) was found in Lake Cibuntu, while the lower average value of DO concentration (5.54 mgL⁻¹) was found in Lake Dora. Seasonally DO concentration showed variability. In Lake Cibuntu highest DO concentration (11.23 mgL⁻¹) was recorded in August 2018 (dry season) and the lowest of DO (5.59 mgL⁻¹) was record in January 1, 2019. In Lake Dora, the highest value of DO (7.41 mg⁻¹) was recorded in September 1, 2018 and lowest DO (2.83 mgL⁻¹) was recorded in April, 2019. In Lake Lotus, the highest DO (8.95 mgL⁻¹) was recorded in September 1, 2018 and the lowest value of DO was recorded in April 2019 (3.68 mgL⁻¹). The low average value of pH was recorded in Lake Dora (5.9). The average pH in Lake Cibuntu and Lake Lotus was similar (6.69 and 6.63) (Figure 3).

Seasonally, the highest pH in Lake Cibuntu, Lake Dora was recorded in dry August 1 (dry season), while the highest value of pH in Lake Lotus was recorded in September 1, 2018 (dry season). The lowest value of pH in Lake Cibuntu, Dora and Lake Lotus was found in December 1, 2018) (rainy season) (Figure 4). The highest conductivity and TDS were found in Lake Lotus with average value of 0.09 mS·cm⁻¹ and 53.4 mgL⁻¹ respectively. The lowest conductivity and TDS value was found in Lake Cibuntu with the average value of 0.055 mS·cm⁻¹ and 33.37 mgL⁻¹ respectively. Conductivity and TDS showed a similar fluctuation during observation. Generally high value of conductivity and TDS was recorded in dry season (August to September 2018) and the lower Conductivity and TDS rainy season (December 2018). The conductivity and TDS increase again From January 2019 to April 2019 (Figure 4).
Figure 3. Maximum water depth, Water temperature and DO in Lake Cibuntu, Lake Dora and Lake Lotus.
Figure 4. Seasonal variation of pH, Conductivity and TDS in lake Cibuntu, Lake Dora and lake Lotus.
Figure 5. Primary Component Analysis (PCA) of Situ Cibuntu (C), Situ Dora (D) and Situ Lotus (L) based on the temperature (Temp), DO, pH, conductivity (Cond), TDS, TN and TP parameters.

The highest total nitrogen (TN) was recorded in Lake Cibuntu (0.835 mgL\(^{-1}\)) and the highest in the lowest of TN was record in Lake Dora (0.627 mgL\(^{-1}\)). In Lake Cibuntu high concentration of TN was record in September to December 2018, While in Lake Dora TN concentration was record in October 2018 (Figure 6). In Lake Lotus distribution of TN was not high variability. High TP concentration in Lake Cibuntu was found in dry season (in August 2018), while in Lake Dora high concentration of TP was found dry season (July 2018). The lowest value of TP in Lake Cibuntu, Lake Dora and Lake Lotus was recorded in December to March 2019.
The differentiation of water depth fluctuation among the lakes observation apparently influenced by water inflow into the Lakes. Variability of water depth in Situ Cibuntu and Situ Lotus was could be influenced by water inflow from the stream. As reported that the hydrological connectivity is more sensitive to changes of water depth in Lake [18]. The lower water depth of Lake Cibuntu recorded in January 2019 and February 2019 (rainy season) may be related to the function of small lakes which is in West Java the water of small lake was also used for irrigation and water supply for domestic in the watershed area. As reported that water level in the water bodies of small lakes varied with changes in rainfall regime, and water regulation for irrigation or water supply [19]. Lake Dora receive water source from the ground water showed more stable water depth compared to Lake Cibuntu and Lake Lotus during one year. Lake Cibuntu and lake Lotus receive water from stream showed a variability of water depth fluctuation, indicated those two lakes have unbalance hydrological and water volume. The lower water depth in Lake Dora in October 2018 might be related to the input of water mainly from the groundwater into this lake due to rainfall in the start of rainy season (October) did not directly flow into the lake but was absorbed into the soil [20]. The variability of temperature value in Lake Cibuntu, Lake Dora and Lake Lotus was common for tropical area, with range from 27.33-32.03 °C, 28.25-31.6 °C and 27.0-32.83 °C. Higher DO in Situ Cibuntu and Situ Lotus in dry season (August and September 2018) may related with higher photosynthesis of phytoplankton. Previous study reported that highest phytoplankton abundance Lake Cibuntu and Lake lotus was found in August and September respectively [20]. The variability of dissolved oxygen (DO) in Lake Cibuntu, Lake Lotus and Lake Dora may be related to the changes of hydro morphological (water depth, water volume) and hydrobiological processes (overgrowth of phytoplankton and metabolism proses) in lake [21]. The stable value of dissolved oxygen (DO) concentration in Lake Cibuntu, Lake Lotus and Lake Dora in high water depth (November to December 2018) indicated a stability of biotic community in those periods. Previous study reported high phytoplankton diversity which indicate high biotic community stability was recorded in high level of water depth [20]. Water level fluctuations can influence the stability of environmental factors in aquatic ecosystem or lakes.[22]. The major factor influence oxygen reduction may be oxygen consumption by bacterial in water column used to decompose rich organic material which come from the run off and stream during rainy season. pH distribution in observed lakes did not showed high variability during observation. Lower pH was recorded in high water depth (December 1, 2018). Higher pH Lake Cibuntu and Lake Lotus in August 1, 2018 and September 1, 2018 may be also related to the high photosynthesis of phytoplankton which was high abundance in those periods [20]

Conductivity and total dissolved solid (TDS) have similar pattern seasonal fluctuation. Conductivity is a function of dissolved solids and it was strongly correlated with total dissolved solids [23]. Seasonally, the lowest conductivity and TDS was recorded in December 2018 (rainy season) or the

![Figure 6. TN and TP distribution in Lake Cibuntu lake Dora and Lake Lotus.](image-url)
highest water depth. The highest conductivity and TDS value was recorded in August 2 and September 1 (in low water depth). Or dry season. The low conductivity during highest water depth (rainy season is due to the dilution effect of rainfall, while low water level in dry season has an effect on accumulation of dissolved ion concentration in waters and increase conductivity and TDS [24, 25]. Dry season is associated with period of low water levels which characterized by high temperature and conductivity in shallow lake (19). Low water depth and high evaporation in dry season could increase the value of conductivity and TDS, while high water depth (rainy season) decrease conductivity and TDS value was also found in this observation.

Seasonally the fluctuation of TN distribution of Lake Cibuntu, Lake Dora apparently followed the water depth fluctuation. High concentration of TN during high water depth indicated TN in L. Cibuntu and L. Dora may be influenced the influxes of TN from the stream and run off which transported into the lake during high precipitation. In lake Lotus the distribution of TN concentration did not follow water depth fluctuation or more stable during observation. The differentiation of TN fluctuation pattern among the observed lakes may be related to the differentiation of morphological and hydrological condition. Lake with a longer hydraulic residence time could retain longer external input of nutrient such as nitrogen in lake. Some studies reported that water bodies with a longer hydraulic residence time tended to retain a larger proportion of external phosphorus, and the correlation between phosphorus load and hydraulic residence time was much stronger in the lakes with higher surface area [26, 27].

Seasonally, distribution of TP concentration apparently related to season of the year. The reduction in TP concentration during the rainy season (November to March 2019) can be corresponded to the dilution effect due to atmospheric precipitation of TP influx of surface runoff, while the higher concentration in July to October in 2018 (dry season) could be effect accumulation of TP concentration. The low and high precipitation during dry and wet seasons in a tropical country great influenced the water quality in water body [28].

The different of physical-chemical in observed lake could be attributed to the differences in morphological features, water sources, and land use types on those lakes. Lake Dora receive water source from ground water was characterized higher and stable water depth, lower pH while Lake Cibuntu and lake Lotus receive water source from the stream and run off which transported into the lake during high precipitation.

4. Conclusion
Seasonal of water depth in observed lakes varied which apparently influenced by seasonal of the year and water source. The seasonal variation of water depth influenced water quality of lakes. Dry season period associated with low water depth were characterized by high conductivity and TDS and TP concentration and rainy season during high water depth was characterized low TP concentration. In term of nutrient, it showed a different pattern of variability fluctuation between observed lakes.

5. References
[1] Nirmal Kuma J I, Oommen C 2011 Applied Ecology and Environmental Research 9 279-292.
[2] Weijters M, Janse J H, Alkemade R, Verhoeven JTA 2009 Marine and Freshwater Ecosystem 19 104–112.
[3] Wang L, Hua Li H, Jinhua Dang J, Zhao Y Yu’en Zhu Y Qiao P 2020 Journal of Chemistry p 9. https://doi.org/10.1155/2020/865348.
[4] Elliott S and Sorrel B 2000 Lake Manager’ Hanbook. Land-Water Interaction (New Zealand: Ministry for the Environment) p 76.
[5] Hadiaty R K 2011 Ikhtiologi Indonesia 11 143-157 (in Indonesia).
[6] Department Pekerjaan Umum 1986 Inventarisasi situ-situ di wilayah Jabotabek Bappeda Daerah Tingkat I Jawa Barat p 94.
[7] Sudiana T W 2018 J. Air Indonesia 10 23–33 (in Indonesia)
[8] Nesseli-Flores J 2008 Urban Lake: Ecosystem at Risk, Worthy of the Best Care. Proc. of Taal 2007 12th World Lake Conference: 1333-1337.
[9] Henny C, Meutia A A 2013 Urban Lakes in Megacity Jakarta: Risk and Management Plan for Future Sustainability *Procedia Environ. Sci.* 20 737–74.
[10] Cufney T F, Kennen J G, and Waite I R 2014 Aquatic ecosystems as indicators of status and trends in water quality 1 122–126.
[11] Aladesanmi O T, Kayode Agboola F, and Adeniyi I F 2014 *Environmental Energy and Biotechnology* 76 42–46.
[12] Li K, Wang L, Li Z, Xie Y, Wang X, Fang Q 2017 *Water* 9 707.
[13] Chen Y, Qin B, Teubner K, Dokulil M T 2003 *J. Plankton Res.* 29 641–647.
[14] Shen P, Shi Q, Hua Z, Kong F, Wang Z, Zhuang S, Chen D 2003 *Environ. Int.* 25 445–453.
[15] Sulastri, Akhdiana I, Khaerunissa N 2021 *IOP Conf. Ser.: Earth Environ. Sci.* 477 012016.
[16] Perdinan, Adi R F, Yon Sugartro Y, Arifah A, Arini E Y and Atmaja T 2017 *IOP Publishing IOP Conf. Ser. Earth Environ. Sci.* 54 012031. doi:10.1088/1755-1315/54/1/012031.
[17] APHA 1999 *Standard methods for the examination of water and wastewater* 20th edition (Washington: American Public Health Association) p 10-176.
[18] Li Y, Qi Zhang Qi, Liu X, TanZ, Yao J 2021 *Stochastic Environmental Research and Risk Assessment* 35 861–879.
[19] Sharip Z, Fatimah Y, Aminuddin J 2018 *International journal of Environmental Science and Technology* 16 4.
[20] Sulastri, Aakhdiana I 2021 *IOP Conf. Series: Earth and Environmental Science* 744 012083.
[21] Cesonien’ė L, Šileikien’ė D, Midona Dapkien M 2020 *Water* 12 500. doi:10.3390/w12020500.
[22] Kolding J and van Zwieten PAM 2012 *Fish. Res.* 115 99–10.
[23] Abhilash H, Mahadevaswamy M, MAHADEVASWAMY 2021 *Current World Environmen*, 16 514-529
[24] De Klerk A R, De Klerk L P, Chamier J, Wepener V 2012 *Water SA* 38 663–672. https://doi.org/10.4314/wsa.v38i5.3.
[25] Pettit N E, Jardine T D, Hamilton, Sinnamon V, Valdes D, Davies P M, Douglas M M, Bunn S E 2012 *Mar. Freshwater Res.* 63 788–800. https://doi.org/10.1071/MF12114
[26] Teck-Yee Li, Gerunsn N, Chen-Lin S, Nyanti L, Siong-Fong S, Jongkar Grinang J 2017 *Journal of Chemistry* p 16. https://doi.org/10.1155/2017/8153246.
[27] Kāiv, T, Nõges T, Laas A 2011 *Hydrobiologia* 660 105–115.
[28] Teck-Yee L, Gerunsn N, Chen-Lin S, Nyanti L, Siong-Fong S, Grinang J 2017 *Journal of Chemistry* p 16. https://doi.org/10.1155/2017/8153246.
[29] Sulastri, Harsono E, Suryono T, Ridwansyah I 2008 *Oceanologi dan Limnologi di Indonesia* (OLDI) 34 307-332.

6. Acknowledgements.
Funding support for this study providing by research grant from Indonesian Government (DIPA-APBN) through Research Centre for Limnology, Indonesian Institute of Sciences. The authors wish to thank to Dr. Lukman and MS. Eva and Ms Siti Aisyah for their supporting in field survey