Urban lake management strategy: Effect of distinct types of lake surroundings and shorelines landscape development on water quality of urban lakes in Megacity Jakarta

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ABSTRACT

The need to understand how the shallow urban lakes respond to the broad-ranging impacts of distinct types of lake surrounding and shoreline landscape development is becoming increasingly important especially associated with eutrophication problems to develop management strategy in maintaining urban lake's water quality. This study examines what important indicators related to distinct types of lake surroundings and shoreline landscape development affect an urban lake water quality in relation to nutrient and organic pollution. We examined the water quality of 9 urban lakes in megacity Jakarta with distinct types of lake surroundings based on the type of inhabitant around the lake catchment's area i.e. urban village (dense irregular residential housing), rural village (agricultural area and few residential housing); rural-urban village (mixed rural and urban village); sub-urban village (mixed planned residential and irregular housing with less green area) and urban-industrial area (mixed urban village and industrial area). Shoreline landscape development in lakes included natural shoreline (with green open space), natural-artificial shoreline (lack of green open space with concrete jogging tract) and artificial shoreline (no or less vegetated cover, concrete retaining wall and concrete jogging track). Lakes in rural village with natural shoreline and various types of vegetation in lake's demarcation area, lake littoral habitats are still well maintained indicated by the presence of submerged aquatic and emergent plants and spotted several types of dragonflies and butterflies. These lakes have good water quality with less turbid water, and low COD, TN, TP, and chlorophyll-a concentrations. The lakes were classified from mesotrophic to eutrophic. Two lakes were considered hypereutrophic with indication of blooming of toxic cynobacteria of microcystis. Although still receiving sewerage, storm water and agricultural runoff the lakes in this rural village type of lake surroundings with natural shoreline landscape can maintain better water quality than those in other types of lake surrounding and shoreline landscape. Vegetation coverage in lake's shoreline and littoral habitat elements such as the presence of submerged and emergent aquatic plants should be managed to improve water quality on urban lakes. These are the important factors for urban lake management strategy to conserve urban lakes.

Keyword: urban lakes, water quality, management strategy, megacity

INTRODUCTION

Rapid urbanization has greatly impacted on the degradation of water resources. Some urban lakes in megacity Jakarta have suffered from water pollution due to point and non-point sources originating from surface run off and discharge of domestic and industrial waste water.

One of the most serious problems of water pollution is eutrophication due to nutrient overloading especial phosphorus loads where the lakes experience the excessive algal blooming including nuisance toxic cyanobacteria of microcystis and sometimes the lakes surface covered by invasive floating and submerged aquatic macrophytes (Birch and McCaskie, 1999; Priadie, 2011, Prihantini et al 2008; Sulawesty et al, 2012). Urban lakes tend to become more eutrophic and greener than non-urban lakes (Schueler and Simpson, 2001; Naselli-Flores, 2008). The eutrophication problem has caused lake reducing its carrying capacity and losing its ecosystem service such as water supply, recreation, fishing or some other direct human use.

Unlike natural lakes, urban lakes have distinct types of surroundings types and large catchment area with impervious cover such as pavement, roads and buildings and often lack of substantial vegetation cover which has strong influence to the lakes. Alteration of lake's natural shoreline vegetation and the lake littoral zone can adversely impact lake's flora and fauna (Schueler and Simpson, 2001). Pressures of the shoreline development can include increasing phosphorus loading and storm water runoff to the lakes. Previous study indicates that the impacts of urbanization and shoreline development with distinct surroundings types on the lakes in megacity Jakarta have aggravated the degradation of urban lake's water quality. Besides having high risk of area shrinkage and siltation/sedimentation, the lakes also have high risk of water pollution and eutrophication problems (Henny and Meutia, 2013). High nutrient and organic concentrations were detected in several urban lakes in megacity Jakarta (Henny and Meutia, 2013).

The need to understand how the shallow urban lake responds to the broad-ranging impacts of distinct types of lake surrounding and shoreline landscape development is very important especially associated with eutrophication problems to develop management strategy in maintaining urban lake's water quality. Lakes have experienced both algal blooms and invasive aquatic weeds. Aquatic weeds present a great challenge to manage lake's water quality due to the fact that they derive their nutrients from bottom sediments and not water column (Schueler and Simpson, 2001). However, the present of controlled native submerged macrophytes can improve water quality and reduce the eutrophication problem in the lake. The eutrophication by algal bloom has caused natural submerged macrophytes disappear and caused the lake ore turbid (Schueler and Simpson, 2001; Hilt et al, 2006; Amano et al, 2008). This paper is aimed to examine the water quality especially in association with eutrophication problem in several urban lakes in megacity Jakarta according to the types of lake surroundings and shorelines development and propose possible management strategy.

METHODOLOGY

The urban lakes examined are in the area of megacity Jakarta which is basically the capital city of Jakarta and surrounding regions. The area of megacity Jakarta is known as Jabodetabek (Jakarta, Bogor, Depok, Tangerang and Bekasi) which can be seen in Fig. 1. Selected lakes for this study are located in Jakarta, Bogor, Depok and Tangerang area. Nine urban lakes with distinct types of surroundings and shorelines development in megacity Jakarta area has been selected to be examined their water quality association with the eutrophication problems. The types of lake surroundings identified according to the criteria from the previous study (Henny and Meutia, 2013). Location and description of nine lakes selected in this study can be seen in Table 1.

Fig. 1. Location of megacity Jakarta (a: Indonesian map by Google Map, 2103 and b: the regions composed of Megacity Jakarta by Mimura (RIHN Researcher, 2013).

Physical and chemical parameters measurements included temperature, pH, turbidity, conductivity, salinity, Dissolved Oxygen (DO), total dissolved solids (TDS) and Secchi Depth (SD). The measurements were conducted by using the Water Quality Checker (WQC, Horiba U). Lake water was sampled at the middle of lakes for lab measurements such as Chemical Oxygen Demand (COD) as organic material parameter, nutrient (total nitrogen and phosphate) and chlorophyll-a concentration. The measurements and the water sampling were done in March and May 2014. The analyses of COD, total N and P were done by using HACH method procedure (HACH, 2005). Chlorophyll-awas measured by using a spectrophotometer (HITACHI) according to the standard method procedure (APHA, 2005).

Trophic status index (TSI) also was calculated to classify the trophic status of the lakes by using equation from Carlson and Simpson (1996). Correlation analysis was done by using Statistical Analyses (SYSTAT). The types of riparian and submerged macrophytes were also observed visually.

Table 1. Location and description of lakes selected in this study (The image by Google Earth, 2014)

Lake	Surroundings type	Description
TONJONG 	***Rural Village:*** (Residential and > 50% green area and agricultural area: Natural-artificial shoreline (60% green open space)	Located in Bogor area; S 6^{o}29’43.43” E 106^{o}45’59.95”; Elev. 155 m. Area: 14.43 ha 60% around the lake bank with retaining (concrete wall) and the rest is natural bank dominated by the grass type of riparian vegetation; No submerged aquatic plant; Less turbid water. One unit floating cage fishery is in the middle of lake.
DORA 	***Rural Village:*** >95% green area (big trees). Lakeis in the Ecopark area. Natural shoreline (100% green open space)	Located in Bogor area; S 6^{o}29’36.41” E 106^{o}51’13.64”; Elev. 148 m. Area: < 1 ha. Lake with natural type of bank and many types of riparian vegetation. Several types of emergent plant on the edge side of lake and all lake area dominated by submerged plant of *Hydrilla sp*. The water is slightly clear and less turbid.
CIBUNTU 	***Rural Village:*** >90% green area (big trees); Shoreline is dominated by big trees. (95% green open space with concrete jogging track)	Located in Bogor area; S 6^{o}29’27.67” E 106^{o}51’04.80”; Elev. 149.3 m Area: 2.11 ha Lake with natural type of bank and grass type of riparian vegetation. Few types of emergent plant on the edge side of lake and 10% of lake area is covered by submerged plant of *Hydrilla sp*. The water is less turbid.
KEMUNING 	***Agricultural Area:*** > 80% agricultural and plantation and green area and < 20% residential area; Natural shoreline is dominated by big trees and 1% concrete track	Located in Bogor area; S 6^{o}30’24.37” E 106^{o}46’53.75”; Elev. 156.7 m Area: 21 ha 20% around the lake bank with retaining (concrete wall) and the rest is natural earthy bank; No riparian vegetation and submerged aquatic plant; Slightly turbid water.
CIKARET 	***Rural-Urban Village:*** >20% residential (mixed regular and irregular housings) And <70% green and agricultural area. Natural-artificial shoreline (70% green open space and <10 % concrete track)	Located in Bogor area; S 6^{o}28’12.00” E 106^{o}5011.67”; Elev. 130.7 m Area: 29.5 ha 50% around the lake bank with retaining (concrete wall) and the rest is natural bank with grass type of riparian vegetation;30% of shoreline with green open space. No submerged aquatic plant; Slightly turbid and light green water.

Table 1. Continued

Lake	Surroundings type	Description
BABAKAN 	***Sub-Urban Village:*** >90% residential (planned regular housings and irregular housings); <1% green. Artificial shoreline (no or less vegetated cover, concrete retaining wall and concrete jogging track).	Located in Jakarta area; S 6°20’31.41” E 106°49’25.53”; Elev. 64.3 m Area: 32 ha All around the lake bank with retaining (concrete wall). The shoreline is covered with concrete road with almost <1% green open space. No indication of aquatic plant. Slightly turbid and light green water.
GINTUNG 	***Sub-Urban Village:*** >80% residential (regular and irregular housings); <10% green and agricultural area. Natural shoreline and 5% concrete track	Located inTangerang area; S 6°18’33.60” E 106°45’49.19”; Elev. 48.3 m Area: 31 ha 90% around the lake bank is natural bank with the grass type of riparian vegetation; Indication of water hyacinth and water spinach at the edge side of lake; The water is dark green with indication of algal blooming and toxic algae of macrocystis.
RAWA BESAR 	***Urban Village:*** 100% residential (Dense irregular housings) Artificial shoreline with concrete track	Located in Depok area; S 6°23’42.11” E 106°48’55.87”; Elev. 96 m Area: 17 ha. 80% around the lake bank retaining (concrete wall); No green open space and all shoreline and lake side covered by very dense housing. The water is dark green with indication of algal blooming and toxic algae of macrocystis. There are several units of floating cage fishery on the lake.
RAWA KALONG 	***Industrial-Urban Village:*** 75% industrial compound and < 30% dense irregular housings). Natural and artificial shoreline.	Located in Depok area; S 6°23’40.61” E 106°52’07.70”; Elev. 155 m Area:11.21 ha 60% around the lake bank retaining (concrete wall) and the rest with natural bank; < 5% of green open space and all shoreline and lake side is industrial buildings and dense housings. The water is green with indication of algal blooming. There are several units of floating cage fishery on the lake.

RESULT AND DISCUSSION

Nutrients as TN and TP, chlorophyll-a and organic matter as COD concentrations were quite high in the lakes in sub-urban, industrial and urban village with more artificial shoreline development (Table 2). Besides storm water runoff and sewage inflow, floating cage fishery in the lakes such as Gintung, Rawa Besar and Rawa Kalong has contributed more nutrient and organic loading to the lakes. High organic and ammonia concentrations also reported in Situ Gintung (Kristiana, 2003). High Nutrient pollution from N and P loadings have been causing severe eutophication problems in most of lakes especially in shallow urban lakes which

Table 2. Nutrient, chlorophyll-a and COD concentrations in urban lakes

Lake	Surroundings Type	Shoreline Development	TN mg/L	TP mg/L	Klorofil-a mg/m3	COD mg/L
Tonjong	Rural Village	Natural-Artificial	1.086 - 2.684	0.014 - 0.309	0.719	82.26
Dora	Rural Village	Natural	0.610	0.014	2.648	43.548
Cibuntu	Rural Village	Natural	0.763	0.026	5.472	35.484
Kemuning	Agricultural Area	Natural-Artificial	1.232	0.026	1.477	80.645
Cikaret	Rural-Urban Village	Natural-Artificial	1.757 - 3.029	0.037 - 0.074	1.867	98.387
Babakan	Sub-Urban Village	Artificial	1.161 - 3.100	0.031 - 0.315	5.585	172.581
Gintung	Industrial-Urban Village	Natural-Artificial	1.778 - 3.384	0.117 - 0.331	46.650	141.935
Rawa Besar	Sub-Urban Village	Natural- Artificial	2.065 - 2.069	0.187 - 0.318	43.734	169.355
Rawa Kalong	Urban Village	Artificial	1.538	0.379	35.774	72.581

indicated by dark green water color as a sign of green algae blooms and sometimes with excessive macrophyte coverage on the water surface. Lakes Gintung, Rawa Besar and Rawa Kalong contained a very dark green water color and in some parts of the lakes the green scum was spotted indicating the presence of nuisance blue green algae cyanobacteria. As in Lake Gintung, floating water hyacinth and water spinach were spotted on the lake periphery. Several lakes with surroundings type of urban village and agricultural area in megacity Jakarta has been reported to have problem with cyanobacteria contamination and invasive floating macrophyte coverage from the type of *Eichornia sp.* (Priadie, 2011; Prihantini et al, 2008; Kristiana, 2003; Sulawesty et al, 2012). Agriculture and urban runoff usually carry high loads of N and P from the fertilizer. Previous study on several shallow lakes in rural area and natural shorelines also indicates lower TN, TP and chlorophyll-a concentrations, while the lakes in agricultural area contain higher TN, TP and chlorophyll-a concentrations (Sulastri, et al, 2008). Lake Kemuning contained lower nutrient and chlorophyll-a concentrations although in the area of more agricultural surrounding type, lake's shoreline area is planted with more trees, and very small percentage of artificial shoreline development. The agricultural activity on the lake catchment's area was more plantation of wooden tress. Lake Babakan is in the sub-urban village with artificial shoreline development has the highest COD concentration but has slightly low chlorophyll-a concentration. Lakes in rural village apparently have better water quality and no indication of eutrophication problems by algal blooming. Lakes Dora and Cibuntu which are in rural village with natural shoreline development contained less COD concentrations and TP concentrations. Both lakes indicates widely spread of submerged macrophytes of *Hydrilla verticilta* in the shallower area of lake's bottom, however Lake Dora's bottom entirely covered by *Myriophyllum verticillatum*. The lake shorelines also dominate by emergent plants. On the other hand, in Lake Cibuntu only on the inlet area and shallower area indicates dominant coverage of submerged macrophytes which counts < 5% of lake surface area.

Direct measurements of physical and chemical properties of lake's water in each surroundings type indicate different water quality (Table 3). Lake water pH values are in the range from neutral to very alkaline. The lakes in rural village and in more natural shoreline development indicated better water quality with lower pH, conductivity, total dissolved solids (TDS) and less turbid water and slightly higher *secchi depth* (SD) than those of lakes in sub-urban village, industrial and urban village. Turbidity for clear unpolluted water is usually < 30 NTU (Weiner, 2000). High dissolved oxygen (DO) of > 6 mg/L indicates the water is in good condition to support aquatic lives. Water quality standard to sustain better aquatic lives especially for sensitive fish, DO should be maintained at least 5 mg/L for tropical water (Weiner, 2000). Eutrophic lake usually will give high DO and pH values during the day in the sunny condition due to photosynthesis process by phytoplankton (green algae) that produces high oxygen level and pH from CO_2 uptake. However, during the night time all aquatic organisms including green algae consume oxygen causing rapid depletion of oxygen in the lakes (Wetzel, 2001). Oxygen deficit in the lake water to a level < 3 mg/L could lead to fish kill. Fish kill has been frequently occurred in Lake Maninjau when the water condition become hypereutrophic with nuisance cyanobacteria blooms (Sulastri et al, 2001). The lakes observed in this study have higher DO values during day sampling especially in the lakes with obvious green water color in sub-urban and urban village. Low DO and pH concentrations detected in Lake Babakan were probably due to high organic matter concentration and low phytoplankton abundance indicated by low chlorophyll-a concentration. Better flushing system probably might flush the phytoplanton from the lake.

In comparing with other results in the past years from other reports, water quality of lakes Gintung (Kristiana, 2003), Rawa, Besar (DLH, Depok, 2010, 2011), Rawa Kalong (Sulawesty et al, 2012), and Babakan (Prihantini, 2008, BLH, DKI Jakarta, 2011 and 2012), are degrading however more improved water quality for lake Cibuntu due to rehabilitation program in year 2000 (Tarigan, 2008).

Table 3. Physical and chemical characteristics of urban lakes water

Lake	Surroundings Type	Shoreline Development	Suhu (^oC)	pH	Salinitas (ppt)	Conductivity (mS/cm)	TDS (g/L)
Tonjong	Rural Village	Natural-Artificial	30.2	6.73	0	0.075 - 0.087	0.0442
Dora	Rural Village	Natural	30.1	5.9	0	0.068	0.0407
Cibuntu	Rural Village	Natural	29.7	6.53	0	0.093	0.0558
Kemuning	Agricultural Area	Natural-Artificial	30	6.41	0.1	0.16	0.0631
Cikaret	Rural-Urban Village	Natural-Artificial	30.3 - 30.6	6.74 - 6.94	0.1	0.13 - 0.145	0.0764
Babakan	Sub-Urban Village	Artificial	29.5 - 31.2	7.14 - 7.58	0.1	0.225 - 0.231	0.1311
Gintung	Industrial-Urban Village	Natural-Artificial	30.6 - 32.1	8.54 - 8.55	0.1	0.169 - 0.201	0.97
Rawa Besar	Sub-Urban Village	Natural- Artificial	30.8 - 30.4	9.17 - 9.46	0.1	0.221 - 0.228	0.1291
Rawa Kalong	Urban Village	Artificial	29.8	9.05	0.1	0.128	0.083

Table 3. Continued

Lake	Surroundings type	Shorline development	Secchi Depth [SD](m)	Turbiditas (NTU)	DO (mg/L)
Tonjong	Rural Village	Natural-Artificial	1.2	22	7.58 - 7.61
Dora	Rural Village	Natural	0.93	35	7.35
Cibuntu	Rural Village	Natural	0.85	42	7.76
Kemuning	Agricultural Area	Natural-Artificial	0.57	59	NA
Cikaret	Rural-Urban Village	Natural-Artificial	0.78	47	9.38 - 11.41
Babakan	Sub-Urban Village	Artificial	0.81	45	3.45 - 5.2
Gintung	Industrial-Urban Village	Natural-Artificial	0.28	75	11.78 - 12.81
Rawa Besar	Sub-Urban Village	Natural- Artificial	0.23	81	18.27 - 19
Rawa Kalong	Urban Village	Artificial	0.255	80	17.63

Chlorphyll a concentrations in lakes are usually associated with nutrient concentratios especially phosphorus. Phosphorus in lake has been usually limiting nutrient (Wetzel, 2001; Yang et al, 2013). Pearson correlation coefficients between Chlorphyll-a and TP, TN, and turbidity indicate significantly positive correlation, but inversely correlated with ratio of TN:TP, and secchi depth (Table 4). High chlorophyll-a concentrations apparently increase turbidity and reduce secchi depth indicating decrease in light penetration to the water column, however chlorophyll-a is not the only factor contribute to high turbid water. Solids concentration is one of the factors to increase water turbidity. Turbid water also decreases secchi depth of the lake. Chlorophyll-a always had higher correlation with TP than TN, the same observation also reported for other urban shallow lakes (Lu et al, 20110).

Table 4. Person correlation coefficient between parameters

	Pearson Correlation Coefficient
TN/TP:CHL	-0.8700
CHL:TP	0.9561
CHL:TN	0.6508
CHL:SD	-0.8747
CHL:Turbid	0.8696
SD:Turbid	-0.9979

Note: TN/TP (ratio TN and TP); CHL (chlorophyll-a); SD (Secchi Depth); Turbid (turbidity)
Significant at $p<0.01$

Trophic status index (TSI) is a common index to classify the trophic status of lakes. There are several equations to calculate the TSI based on nutrient concentrations of phosphorus, chlorophyll-a and secchi depth and in some condition of nitrogen limiting in lake, nitrogen concentration can be used to calculate TSI. Cholrphyll-a is usually the best predictor than either of the other three indices. According to Carlson and Simpson, 1996 averaging the three latter variables rather than to prioritize their use to calculate the TSI is considered making no sense at all. Therefore in this study, TSI calculations were done using all variables. The trophic status of lakes will be based on ranging of TSI values. The strong correlation between TSI values and chlorophyll-a considered the factor determines the chlorophyll-a concentration in the lake and furthermore the eutrophication problems. The results can be used to achieve efficient urban lake management in reducing the eutrophication problems.

Figure 2 shows the trends of TSI values for all variable and the association of all variables including chlorophyll-a and ratio of TN:TP. The cross line indicates boundary for TN:TP ratio and TSI values classify the trophic status of lakes. The boundary condition between mesotrophic and eutrophic conditions lies on TN:TP ratio=20 and on TSI values > 50 according to each variables. Strong positive correlation also are indicated by the correlation of Chlorophyll-a and TSI(P), TSI(CHL), and TSI(SD) but showing slightly lower Pearson correlation coefficient with TSI(N (Table 5). The latter TSI of three variables can be use as the best predictor for lake status trophic. The boundary condition values of this study are consistent with Carlson and Simpson's number. Previous study in a shallow lake in China also obtained the same results on the TN:TP ratio value, where the TN:TP ratio value of < 20 in the lake indicate no sign of eutrophication and the phosphorus is the limiting nutrient to the lake (Yang et al, 2013).

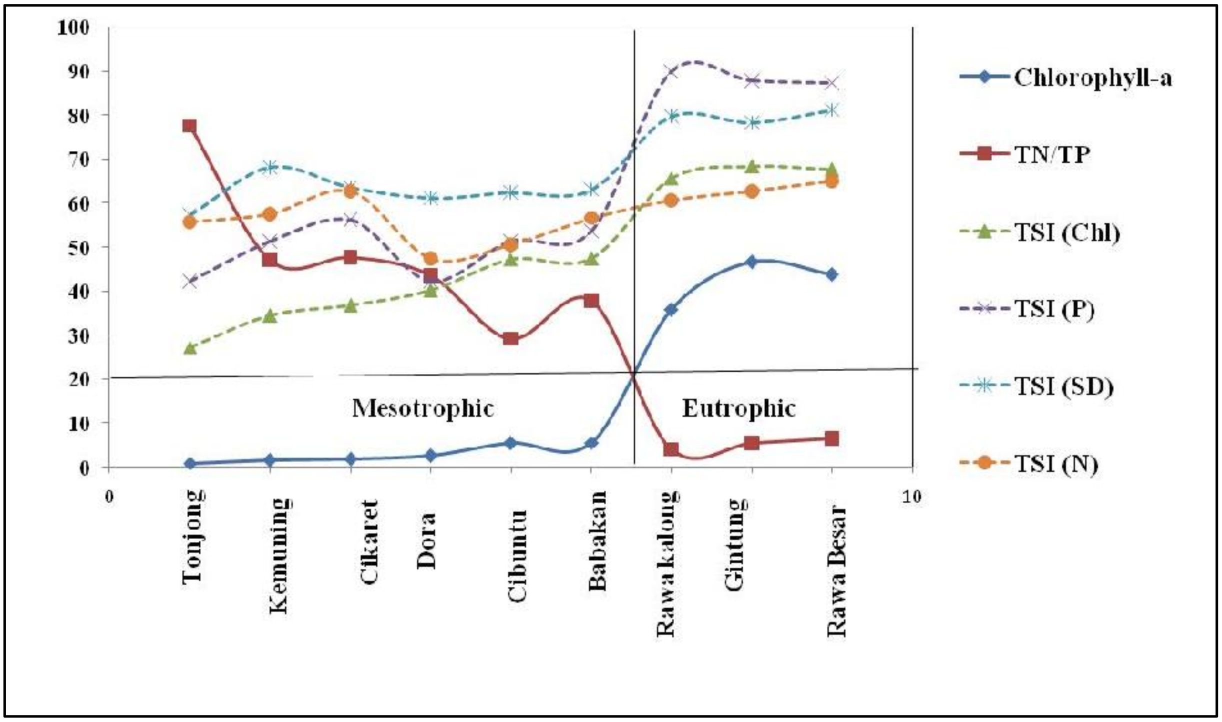

Fig. 2. Trend of TSI in association with TN/TP ratio and chlorophyll-a

Table 5. Person correlation coefficient

	Pearson Correlation Coefficient
CHL:TSI (CHL)	0.94179
CHL:TSI (P)	0.96196
CHL:TSI (SD)	0.93573
CHL:TSI (N)	0.65148

Note: CHL (chlorophyll-a); SD (Secchi Depth); Significant at $p<0.01$

To make certain that phosphorus is the main factor of controlling the algal blooms the value of ratio of chlorophyll-a:TP can also be used. The ratio value measures the efficiency with which TP is transferred into algal blooms (i.e. as an indicator of P limitation) (Spears et al, 2013). The lakes which indicated the eutrophication problems with algal bloom had lower ratio of chlorophyll-a:TP (Fig. 3). All results suggest that P can be limiting nutrient and is the major factor controlling the eutrophication of algal blooms problems in the urban lakes studied.

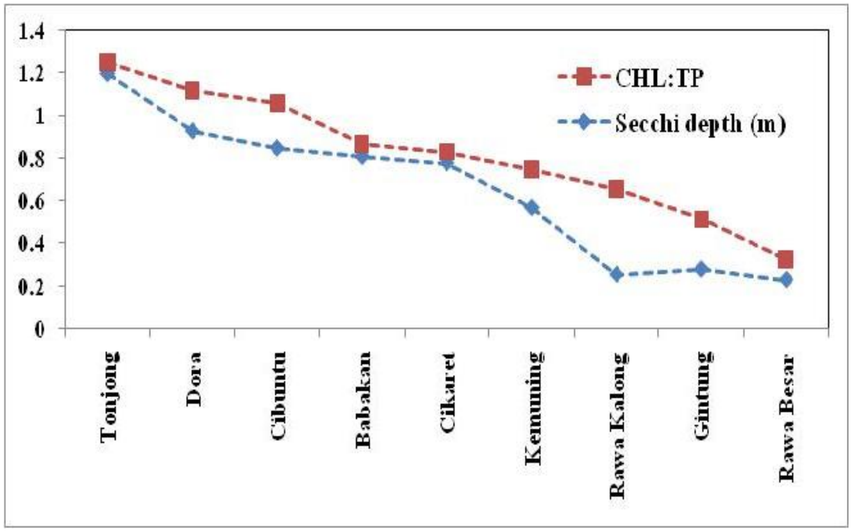

Fig. 3. Trend of CHL:TP ratio and secchi depth

The lakes classification based on the trophic status according to Carlson and Simpson (1996) ranged from mesotrophic to hypereutrophic conditions (Table 6 and 7). Lake Tonjong which classified from oligotrophic to mesotrophic conditions based on the TSI values, however based on the secchi depth the lake was considered eutrophic. Lower secchi depth or more turbid water but low chlorophyll-a concentration can be resulted from high organic matter and solids concentration. Lakes in sub-urban village used for floating cage fishery (Gintung), urban village (Rawa Besar) and mixed industrial-urban village (Rawa kalong) were in hypereutrophic conditions with indication of dense algal blooms, algal scum and floating macrophytes and absence of submerged macrophytes.

Eutrophication problem has known to reduce water clarity, decline in fish community, increase nuisance algal blooms and possible fish kills due to low dissolved oxygen and decrease the health of lake's ecosystem by far decreasing the amenity of urban lives. Figure 4 shows one of the urban lakes indicating the eutrophication problems with algal scum and microcystis and widely spread of *Hydrilla verticillata* and controlled emergent plant.

Table 6. Trophic status based on TSI score, concentrations of chlorophyll-a (CHL), Total phosphate (TP) and secchi depth (SD) according to Carlson and Simpson (1996)

TSI	CHL (μg/L)	TP (μg/L)	SD	Trophic Status	Problems
<30	<0.95	<6	> 8	Ultraoligotrophic	Clear water, oxygen hypolimnia
30 -40	0.95 - 2.6	6 - 12	8 - 4	Oligotrophic	Slight clear water, anoxic hypolimnia in shallower lake
40 - 50	2.6 - 7.3	12 - 24	4 - 2	Mesotrophic	Water moderately clear, anoxic hypolimnia
50 - 60	7.3 - 20	24 - 48	2 - 1	Eutrophic	Anoxic hypolimnia, macrophyte problems possible
60 - 70	20 - 56	48 - 96	0.5 - 1	Eutrophic	Blue-green algae dominate, algal scums and macrophyte problems
70 - >80	56 - > 155	96 - > 192	0.5 - <0.25	Hypereutrophic	Dense algae and macrophyte, or algal scums, few macrophyte

Table 7. Trophic status of the urban lakes based on the range of TSI values

Lake	Surroundings Type	Shoreline Development	TSI	Classification
Tonjong	Rural Village	Natural-Artificial	27 - 57	Oligotrophic-Mesotrophic
Kemuning	Agricultural Area	Natural-Artificial	34 - 68	Mesotrophic-Eutrophic
Cikaret	Rural-Urban Village	Natural-Artificial	37 - 64	Mesotrophic-Eutrophic
Dora	Rural Village	Natural	40 - 61	Mesotrophic-Eutrophic
Cibuntu	Rural Village	Natural	47 - 62	Mesotrophic-Eutrophic
Babakan	Sub-Urban Village	Artificial	47 - 63	Mesotrophic-Eutrophic
Rawa Kalong	Industrial-Urban Village	Natural-Artificial	61 - 90	Eutrophic-Hyper Eutrophic
Gintung	Sub-Urban Village	Natural- Artificial	63 - 88	Eutrophic-Hyper Eutrophic
Rawa Besar	Urban Village	Artificial	65 - 87	Eutrophic-Hyper Eutrophic

Fig. 4. The algal scum, floating macrophytes (left); submerged macrophytes of *Hydrilla verticillata* (middle) and emergent macrophytes (right) in Lakes Gintung and Dora respectively.

The results of this study indicated that surroundings type and shoreline development do have impact on urban lake water quality associated with the eutrophication problems in megacity Jakarta. Lakes with less pressures of urban activity such as rural village with more natural shoreline development and more green open space have better water quality and face lower eutrophication problems. Submerged and emergent macrophytes only observed in Lakes Dora and Cibuntu from all of studied lakes. Both lakes had better water quality and less turbid water. Lake Tonjong also showed also slightly better water quality although no submerged macrophytes observed in the lake and only limited types of riparian macrophytes are present. Lake Cibuntu is slightly well managed based on the growth of submerged macrophyte. Uncontrolled submerged macrophyte in Lake Dora is associated with sedimentation and decrease in lake depth where light penetration can reach lake's bottom. As in Lake Cibuntu, rehabilitation and sediment dredging has increased lake's water quality. Deeper lake can control excessive growth of submerged macrophytes. Tables 8 and 9 present the types emergent and submerged macrophytes in Lakes Dora and Cibuntu (Kurniawan, 2014). Controlled submerged and emergent macrophytes usually prevent algal bloom eutrophication and can maintain aquatic life especially fish in the lake. Submerged mcrophytes can restrain resuspension of bottom sediments which lead to better waer quality of eutrophic shallow lakes (James et al, 2004). More natural shorelines development with green open space, maintained submerged and emergent macrophytes and good water quality can support more aquatic lives including butterflies and dragon flies which have been a bioindicator for good quality aquatic ecosystem.

Based on the results, besides reducing the phosphorus loading to the lakes by managing and treating storm water run-off, sewage inflow and discharge industrial waste water, the lake shorelines should be set more natural with more green open space, and restore the submerged macrophyte and maintain emergent plant in the littoral zone. The re-establishment of submerged macrophytes is essential to manage a long-term stability for clear water condition (Hilt et al, 2006). Restoration attempt of submerged macrophytes in an eutrophic shallow lake in Japan has been successfully (Amano et al, 2008).

Table 8. Types of macrophytes presence in Lake Dora (Kurniawan, 2014)

NO	JENIS	FAMILI	HABITAT	ORIGIN
1	*Hydrilla verticillata* (L.F.) Royle	Hydrocharitaceae	Submerged	Native
2	*Nymphaea lotus* (L)	Nymphaceae	Floating Leaves	Native
3	*Nymphaea lotus* (L) var. rubra	Nymphaceae	Floating Leaves	Native
4	*Panicum repens (* L.)	Poaceae	Emergent	Asia
5	*Equisetum ramosissimum* Desf.	Equisetaceae	Emergent	Native
6	*Hanguana malayana* (Jack) Merr.	Hanguanaceae	Emergent	Native
7	*Typha angustifolia (* L.)	Typhaceae	Emergent	Native
8	*Cyrtosperma johstonii* N.E. Br.	Araceae	Emergent	Native
9	*Lepironia articulata* (Retz.) Domin	Cyperaceae	Emergent	Native
10	*Myriophyllum* sp.	Haloragaceae	Submerged	Native
11	*Ludwigia* sp.	Onagraceae	Floating Leaves	Native
12	*Pontederia cordata* (L.)	Pontederiaceae	Emergent	Native

Table 9. Types of macrophytes presence in Lake Cibuntu (Kurniawan, 2014)

NO	JENIS	FAMILI	HABITAT	ORIGIN
1	*Panicum repens (* L)	Poaceae	Emergent	Native
2	*Ipomoea aquatica* Forsk	Convolvulaceae	Floating Leaves	Native
3	*Polygonum barbatum* (L)	Polygonaceae	Emergent	Native
4	*Myriophyllum verticillatum* (L)	Haloragaceae	Submerged	Native
5	*Mimosa pigra* (L)	Mimosaceae	Emergent	South America

CONCLUSION

Different lake surroundings and shoreline development are indeed to have an impact on lake water quality especially associated with eutrophication problems. Urban village with dense irregular housing, artificial or less natural lake' shorelines development and no storm water run-off, sewage inflow and discharge industrial waste water management has degraded urban lake water quality with high concentrations of nutrients and organic matter and eutrophiction problems by algal blooms in megacity Jakarta. On the other hand lakes with less pressures of urban activity such as in rural village with more natural shorelines development and more green open space, and the presence of submerged and emergent macrophytes in the littoral lake zone have better water quality with less turbid water and low nutrients and organic matter concentration and face little eutrophication problems. Phosphorus is apparently a major factor causing the eutrophiction by algal bloom in the studied urban lakes. Reducing the phosphorus loading to the lakes by managing nutrient input to the lake, setting the lake shorelines with more natural with more green open space, and restoring the submerged macrophyte and maintaining emergent plant in the littoral zone can be a good management strategy to reduce eutrophication problems in urban lakes in megacity Jakarta and to maintain a long-term stability for clear lake water condition.

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