Research article

Seasonal Changes of Water Quality in Cheung Ek Lake, Cambodia

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Abstract Cheung Ek Lake is the biggest wastewater lake inside Phnom Penh City and has massive water and nutrient inflow. Around 70% of rain runoff and wastewater in Phnom Penh flows into Cheung Ek Lake through three main canals: Trabek Canal, Stung Meanchey Canal, and Lou Pram Canal, before discharging into the Bassac River. Since 2008, the rapid urbanization of the satellite city in Phnom Penh has decreased the area of the lake and contributed to the degradation of the lake's water quality. Cheung Ek Lake performs many functions such as flood control, natural wastewater treatment, and provision of water for vegetable production. Previous studies identified the positive and negative impact of lake water on the local ecosystem and human livelihoods. The aim of the current study was to monitor seasonal changes in water quality in Cheung Ek Lake, Cambodia. Additionally, the objectives of this study were to (i) analyze the changes in water quality parameters in the rainy season and the dry season and (ii) describe daily and hourly changes in phosphate (PO_4^{3-}) concentration in the lake. For that, selected chemical parameters such as pH, electroconductivity (EC), phosphate, nitrate (NO_3^-), iron (Fe^{2+}), and dissolved oxygen (DO) were measured in the rainy and dry seasons. In addition, phosphate (PO_4^{3-}) was analyzed hourly for a week in the dry season. The water samples were collected at 3 points: inlet, middle, and outlet of the lake, at a depth of 0.5 m. Water samples were analyzed in situ using a spectrophotometer. The decreased values of EC, NO_3^-, PO_4^{3-}, and Fe^{2+} from inlet to outlet show that the lake has the potential to reduce the nutrient level in both seasons. Phosphate increases at 10 am, 1 pm, and 7 pm indicated that water quality was remarkably affected by daily rush hours of household activities. This further suggested that household activities could be the main sources of the presence of a high concentration of PO_4^{3-} in the lake.

Keywords Cheung Ek Lake, water quality, seasonal change

INTRODUCTION

Scarce freshwater resources are increasingly being used to satisfy the demands of a rapidly increasing population and a growing global economy. The increasing rate of uncontrolled and unplanned urbanization in developing countries in Asia, Africa, and South America is likely one of the most important factors in the decline of the quality of urban water bodies and the increasing health and other associated risks for urban residents (Pankaj et al., 2019).

The major cities in Southeast Asia have millions of inhabitants and a great number of small- and large-scale industries. Often these cities have no formal wastewater treatment facility, and the wastewater is discharged into a drainage system whose main purpose is to prevent flooding of the city. This is also the case for Phnom Penh city. The city of Phnom Penh had a population of 2.3 million people in 2019 (NIS, 2019) and a demographic growth of 3.2% in the period 2008-2019. In 2014, Phnom Penh boasted a total of 97,200 established enterprises, reflecting a 1.4 percent increase compared to 2011 (NIS, 2015). Moreover, only 9 percent of discharged water in Cambodia is properly treated before being released into the main water bodies, making Cambodia the secondlowest capacity after Lao PDR in Southeast Asia (Buth et al., 2019). Until now, there have been no public sewage treatment plants in Phnom Penh and the majority of the industries have been constructed without wastewater treatment facilities. Domestic and industrial wastewater as well as storm water is drained out of the city into Cheung Ek Lake (Takahashi et al., 2002).

Cheung Ek Lake is essential in the treatment of Phnom Penh's sewage and the prevention of devastating floods both in the city center and the southern border town of the city. Acting as a large natural wastewater treatment area, this lake has been found to be semi-effective through the use of plants such as water morning glory and water mimosa, both of which are planted by local aquatic farmers, which assist in cleansing the water of harmful pollutants (Irvine et al., 2015). As the city's wastewater, including sewage, drains directly into the lake through three major canals, the presence of this lake is a natural barrier protecting pollutants from entering the Bassac River downstream. However, the uncontrolled human occupation on the lake's bank has led to encroachment of the lake's surface area every year, especially since 2013 when the satellite cities project started (Sahmakum Teang Tnaut, 2019). As the lake's surface area gets smaller, its potential for wastewater treatment reduces as well. Even though several studies have examined the water quality in Cheung Ek Lake (Irvine et al., 2008; Nara et al., 2015), the study on the changes in the water quality related to seasons is still not being examined yet. Thus, this study aims to address the gaps seen.

OBJECTIVE

The purpose of this study is to monitor the seasonal changes of water quality in Cheung Ek Lake, Cambodia. Accordingly, the objectives of this study are to (i) analyze the changes in water quality in the rainy season and the dry season and (ii) describe daily and hourly changes in phosphate (PO_4^{3-}) concentration in the lake.

METHODOLOGY

The study was conducted on Cheung Ek Lake located south of Phnom Penh city (104°90'–104°94'E and 11°46'-11°53'N). It is the catchment area where 80% of the total wastewater from this catchment is drained into the lake (Van der Hoek et al., 2005). The lake's surface area changes from 1,300 to 3,000 ha approximately from dry to rainy seasons, with an average depth of 0.5-1.5 m in the dry season and 7-9 m in the rainy season. The average annual rainfall is 1,440 mm and the elevation is around 10 m above sea level (Nara et al., 2015). The rainy season is from May to September and the dry season starts from October to May.

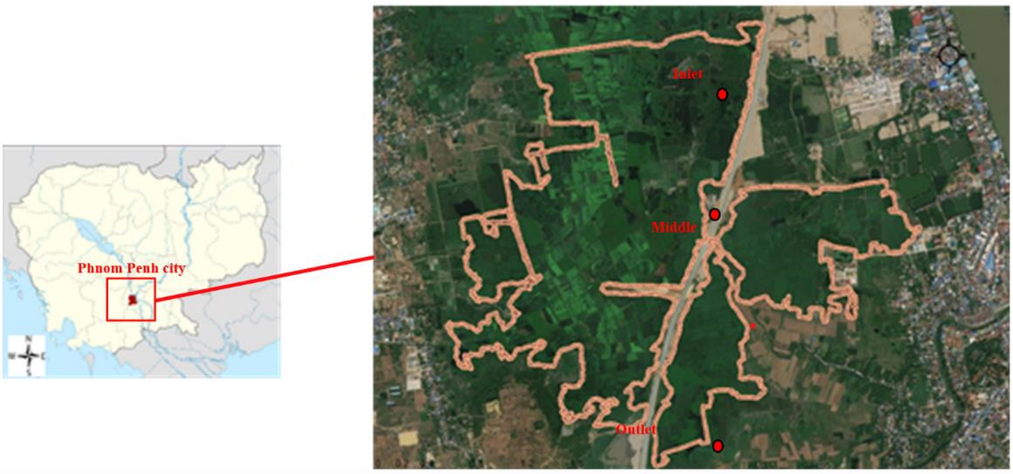

Fig. 1 Map of Cambodia and sampling point in Cheung Ek Lake (Google map)

Water Sampling and Analysis

To analyze the changes in water quality parameters, water sampling was conducted for the rainy season in 2019 and 2020 for dry seasons. Water samples were taken at 0.5 m depth by using Heyroth Water Sampler. Sampled water was kept in the plastic containers at 5°C and transported to the laboratory within 3 h of collection for analysis.

Water samples were analyzed for pH, electrical conductivity (EC), iron (Fe), dissolved oxygen (DO), phosphate (PO_4^{3-}), and nitrate (NO_3^-) using a pH meter, EC meter, and DR 900 portable data-logging colorimeter instrument. The water samples were collected at the inlet, middle, and outlet for 3 days in the rainy season (9th - 11th Sep 2019) and 7 days in the dry season (19th - 25th Dec 2020).

To analyze the daily changes of PO_4^{3-} concentration in the lake, the water sample was taken hourly in the lake from 5 am until 7 pm for 7 days in the dry season (19th - 25th Dec 2020). During this date range, no rainfall was recorded, and the average daily air temperature ranged from 23-30°C. Totally 107 water samples were analyzed for PO_4^{3-} in the inlet point of the lake to determine its possible sources.

RESULTS AND DISCUSSION

The results from Table 1 and Table 2 for pH in both seasons range from 7.06 to 7.7 indicating it base state of the lake's water. The electrical conductivity (EC) decreased from the rainy to the dry season, and one of the primary factors influencing this change in EC levels in the water body could be rainwater. Iron (Fe^{2+}) concentrations ranged from 0.03 to 0.08 mg L^{-1}, which, based on the water pollution control standard in Cambodia for public water areas (20 mg L^{-1}), indicated no sign of Fe contamination (RGC, 2009).

Table 1 Chemical water parameters of the inlet, middle, and outlet of the lake in rainy season

Sampling location	pH	EC (mS/cm)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)	Fe^{2+} (mg/L)	DO (mg/L)
Inlet	7.06 ± 0.30	0.75 ± 0.04	0.66 ± 0.29	5.29 ± 2.26 a*	0.03 ± 0.03	5.14 ± 2.24
Middle	6.98 ± 0.27	0.72 ± 0.01	0.11 ± 0.16	1.42 ± 0.59 b*	0.05 ± 0.05	6.06 ± 1.99
Outlet	7.15 ± 0.36	0.66 ± 0.02	0.55 ± 0.18	1.90 ± 0.50 b*	0.06 ± 0.03	3.55 ± 0.66

*Note: Values are mean ± SD (n=3), * p< 0.1, Source: Data from analysis in Sep 2019*

Table 2 Chemical water parameters of the inlet, middle, and outlet of the lake in the dry season

Sampling location	pH	EC (mS/cm)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)	Fe^{2+} (mg/L)	DO (mg/L)
Inlet	7.7±0.18	0.37±0.04 a*	0.4±0.05	4.64±0.91 a*	0.08±0.04	3.25±0.96 a*
Middle	7.7±0.28	0.36±0.01 a*	0.3±0.26	3.66±0.25 a*	0.06±0.18	6.40±1.02 b*
Outlet	7.6±0.23	0.33±0.01 b*	0.1±0.33	2.56±0.54 b*	0.03±0.09	6.75±0.97 b*

*Note: Values are mean ± SD (n=7), * p< 0.1, Source: Data from analysis in Dec 2020*

Phosphate (PO_4^{3-}) varied drastically in the rainy season, decreasing from 5.29 mg L^{-1} in the inlet to 1.42 mg L^{-1}in the outlet. In both seasons PO_4^{3-} decreases from inlet to outlet point. The drop of PO_4^{3-} concentration in both middle and outlet points may be attributed to agricultural activities occurring on the lake's surface, which absorb the available PO_4^{3-} in the water.

Similar to PO_4^{3-}, nitrate (NO_3^-) concentrations were observed to be decreasing in the dry season suggesting urban run-off. In the outlet point in the rainy season, NO_3^- increase again may be caused by the construction activities nearby. These activities in proximity to the lake have induced water turbulence, leading to the release of sediment from the lake's bottom causing the elevation of NO_3^- level in the outlet point.

Dissolved oxygen (DO) in the lake ranged from 3.55 to 6.06 mg L^{-1} in the rainy season and 3.25 to 6.75 mg L^{-1} in the dry season. The elevated levels of DO observed at the inlet point during the rainy season can be attributed to temperature fluctuations. The wastewater discharged into Cheung

Ek Lake flows from the city through an open channel. In the rainy season, this water becomes diluted with rainwater, leading to a reduction in water temperature. This drop in temperature is responsible for the rise in DO levels. Additionally, the runoff during the rainy season can raise the PO_4^{3-} levels, potentially promoting increased algae growth along the open channel in the city. Algae, in turn, contributes to dissolved oxygen (DO) production in the daytime.

The low and high precipitation during dry and rainy seasons in tropical countries can greatly change the water quality of the lake (Ling et al., 2017). The high precipitation during the wet season can either decrease the pollutant concentration by dilution or deteriorate the lake water quality due to increased surface runoff from anthropogenic activities. Seasonal variations in the water quality of the Cheung Ek Lake have a relatively minor impact on the pH parameter, whereas EC increases because of dilution with rainwater. However, in terms of nutrients such as NO_3^-, PO_4^{3-}, and DO, the water quality exhibits improvement during the dry season.

The concentration indicated in Table 3, Figs. 2 and 3 show the load of four parameters in Cheung Ek Lake between the inlet and outlet site. The result for PO_4^{3-}, NO_3^- showed a decreasing trend. Fe increased in the rainy season and decreased in the dry season, which contrasts with DO in both sites. As the outlet's load was reduced compared to the inlet's load it can be said that the lake can remove inflow pollutants in both seasons.

Table 3 Nutrient loads of the inlet and outlet in the rainy and dry season

Parameter	Inlet	Outlet
NO_3^- (g/s)	28.08	18.65
PO_4^{3-} (g/s)	222.81	64.42
Fe^{2+} (g/s)	1.26	2.03
DO (g/s)	216.50	120.38

Source: Data from analysis in Sept 2019

Parameter	Inlet	Outlet
NO_3^- (g/s)	0.24	0.04
PO_4^{3-} (g/s)	2.74	1.07
Fe^{2+} (g/s)	0.05	0.01
DO (g/s)	1.92	2.84

Source: Data from analysis in Dec 2020

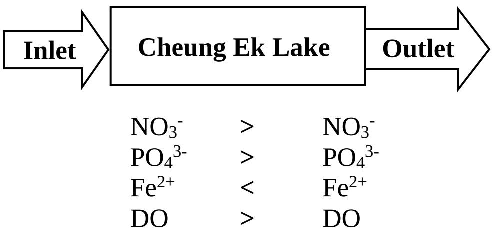

Fig. 2 Function of Cheung Ek Lake in the rainy season

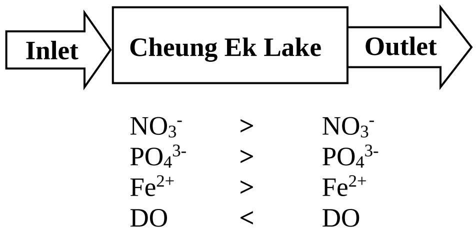

Fig. 3 Function of Cheung Ek Lake in the dry season

Fig. 4 Average PO_4^{3-} in weekend and weekday

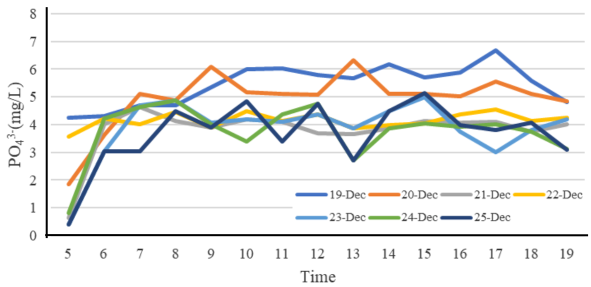

Fig. 5 Hourly Changes in PO_4^{3-}

Figures 4 and 5 indicated the hourly changes in phosphate concentration between weekdays and weekends. Changes in the concentration of PO_4^{3-} can be seen and fluctuate starting from 6 a.m. until 6 p.m. At 5 a.m., the concentration ranges from 1.2 to 3 mg L, while the data at 7 p.m. show a concentration range between 3.5 to 5 mg L. These observations suggest that during the nighttime, particularly on weekdays, concentration experienced a significant decrease. A significant difference was found at 10 am, 1 pm, and 7 pm with confidence levels at 95% and 99%, respectively. The lake's hours represent the busy hours of household activities, which can indicate that the main contribution of PO_4^{3-} level in the lake's water came from the household.

CONCLUSION

According to the findings of this study, the current situation pH and EC of the lake's water did not change much in both seasons, whereas an increase in nutrient levels was seen by comparing the water quality of the dry season to the rainy season, especially in the inlet point. This result indicates the urban run-off of nutrients and suggests the importance of implementing effective management for the inlet point to prevent any further deterioration in the lake's water quality. Furthermore, the result from nutrient loads indicates that the lake's water quality has improved from the input to the output, demonstrating the possibility for potential pollution removal in the lake for both seasons.

Additionally, from the results of hourly analysis of PO_4^{3-}, water quality monitoring should focus more on inlet sites, which are one of the primary sources of pollution. Further research is required to gain a better understanding of PO_4^{3-} and how to address it effectively. Also, when it comes to regulating water discharge from cities, particularly from households, stricter measures should be implemented to control nutrient content.

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