Research article

Evaluation of Water Quality and Vegetable Production in Cheung Ek Lake, Cambodia

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Abstract Wastewater management in Phnom Penh is always a concern for the Royal Government of Cambodia as well as citizens of the capital. All wastewater and sewage from the households and the industries are untreated discharges into the city's wetlands, such as Cheung Ek, Tompun, Trabek Lakes. Cheung Ek Lake is the biggest and terminal lake in the chain of water systems before discharging into Bassac and Mekong River. Apart from the purification of the wastewater, the lake ecosystem also has an important economic function. Local people use the lake for fishing and to cultivate aquatic plants such as water morning glory (*Ipomoea aquatica*) and water mimosa (*Neptunia oleracea*). Considering these aspects, the objectives of this study are to (i) analyze water quality in Cheung Ek Lake during the rainy season; (ii) study the economic balance and the price-chain of water morning glory production. The water samples were collected on three different days at three points in the lake (inlet, middle and outlet) and analyzed for pH, EC, Fe, DO, PO_4^{3-} and NO_3^-. Semi-structured questionnaires were designed for the economic analysis, and a total of 20 farmers were interviewed for social characteristics, input and output costs, and the water morning glory market channel of water morning glory production. Except for phosphate concentrations which was higher at the inlet site, the other nutrient content poses no threat to environmental pollution. Additionally, the lake's chemical load were lower at the outlet than at the inlet. In terms of economic benefit, the net profit from the production was 23.77 USD per day/ha. Despite the fact that the farmers spent a lot of money on hiring the manpower, the profits from the sale was sufficient. The production's economic efficiency was 1.80. The result of water quality and economic showed lake perform a role in removing pollutants and provide economic benefits to the farmers.

Keywords Phnom Penh, Cheung Ek Lake, water quality, water morning glory

INTRODUCTION

The explosive urban expansion throughout Asia has resulted in severe environmental problems, including air and water quality issues and inadequate infrastructure (Varis et al., 2005). In the process of urbanization, economic development and the natural environment are linked by a series of positive and negative effects. Wastewater management has become a concern for the Royal Government of Cambodia since Phnom Penh city's population has grown from 1.4 million in 2008 to 2.1 million in 2018 (NIS, 2019). Until now the city still doesn't have proper wastewater treatment plan while its population continue to grow as well as the expand of city. In the past, the wastewater from the urban are discharged into 3 wetlands namely Tumpon Lake, Trabek Lake, and Cheung Ek Lake (Tharith et al., 2008). The wastewater is serviced by a combined sewer system, and flow is pumped to Cheung Ek Lake (natural wetland) for treatment before it discharges to the Bassac River system (Visoth et al., 2010). However, the urbanization keeps intrude the wetlands area result in only Cheung Ek Lake remained.

Cheung Ek Lake, the largest wastewater Lake in the city, knows as the production area for water morning glory (WG) for almost four decades. The lake's surface area changes from 1,300 to 3,000

ha during the dry and rainy seasons (Nara et al., 2015), given the potential for plant cultivation. This wetland system can potentially provide adequate wastewater treatment, environmental and economic benefits (Brix et al., 2007; Koottatep et al., 2010). However, those study were conducted a decade ago and even before the starting of intrusion into the lake area. The uncontrolled human occupation on the lake's bank has led to encroachment of the lake's surface area every year, especially from 2013 when the satellite cities project started (Sahmakum Teang Tnaut, 2019). Cheung Ek Lake was proven to be effective in treating treated wastewater for bacterial contaminants, nutrients, detergents, and metals (Irivine et al., 2008; Sovann et al., 2011; Visoth et al., 2010). However, as the lake's surface area gets smaller, its potential for wastewater treatment reduce as well. High concentration of phosphorus and deplete level of DO were reported at the point where wastewater from the city discharge into the Mekong rivers (Chea et al., 2016). These could be the result of direct municipal discharges and urban storm water runoff in densely populated areas. Therefore, the question remained whether the lake could still offer ecosystem services to the city.

The purpose of this paper is to investigate the potential of Cheung Ek Lake in ecosystem services in aspect of wastewater treatment and economic benefit. This paper consists of two specific objectives: (i) analyze water quality in Cheung Ek Lake during the rainy season; (ii) study the economic balance and the price-chain of water morning glory (*Ipomoea aquatic*) production.

METHODOLOGY

Study Area

The study was conducted on Cheung Ek Lake located at the south of Phnom Penh city (104°90'–104°94'E and 11°46'–11°53'N). It is the catchment area where 80% of 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 elevation is around 10 m above sea level (Nara et al., 2015).

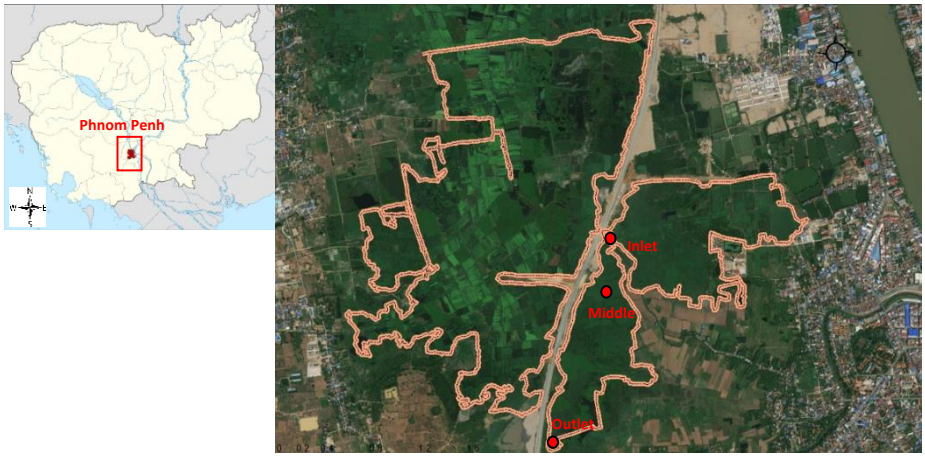

Fig. 1 Map of Cambodia and sampling point in Cheung Ek Lake (Google map)

Water Sampling and Analysis

Water sampling was conducted during the rainy season of September 2019 by using Heyroth Water Sampler. Sampled water was kept in the plastic containers at 5 ^{0}C and transported to the laboratory within 3 h of collection for analysis. The water samples were collected on three different days at the inlet, middle and outlet. Totally 27 water's samples were analyzed for pH, electrical conductivity (EC), iron (Fe), dissolved oxygen (DO), phosphate (PO_4^{3-}) and nitrate (NO_3^-) using DR 900 portable data-logging colorimeter instrument.

Field Survey and Interview

The semi-structured questionnaires were created, and 35 respondents were surveyed. Among 35 respondents are include 20 farmers, 5 middlemen, 5 wholesalers, and 5 retailers whose involved in the production and selling of water morning glory. Social characteristics of the farmers, economic returns and efficiency of the production of water morning glory were analyzed based on semi-questionnaire survey.

RESULTS AND DISCUSSION

The analysis of physical and chemical parameters of water samples are given in Table 1. The result of pH indicates moderately alkaline water in Cheung Ek Lake. The mean pH of Cheung Ek varied from 6.98 to 7.15 at the different sampling sites. Lower pH in the middle point indicates the acidity in the water and could be due to a high concentration of positive hydrogen ion in the water. Electrical Conductivity of Cheung Ek Lake water were not significantly different among sampling sites, varying from 0.66 to 0.75 mS/cm. High conductivity in the lake indicates the mixing of sewage and the rainfall during raining season. Nitrate contents were slightly different from each site, ranging from 0.11 to 0.66 mg L^{-1}. The high concentration in the outlet point, which could be due to the release of the nutrients from sediment where there is no plantation cultivated. The results of PO_4^{3-} varied drastically among different sampling sites in the lake, ranging from 1.42 to 5.29 mg L^{-1}. PO_4^{3-} were maximum at the inlet and become lower in the middle and outlet. The high concentration of PO_4^{3-} in the inlet suggests urban runoff, industrial wastewater and chemicals used in the water for agriculture activities. The low concentration of Iron (Fe) were observed in the outlet of the lake and ranged from 0.03 to 0.05 mg L^{-1}. DO of the lake ranged from 3.55 to 6.06 mg L^{-1}. The maximum concentration of DO were at the inlet and lower at the outlet. This further indicated the flow rate of the lake at different sites and the process of dissolved solid breakdown through self-pollution regulating mechanisms of the lotic water system.

Table 1 Discharge and chemical properties of inlet, middle and outlet of the lake

Location	Discharge (m^3/s)	pH	EC (mS/cm)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)	Fe (mg/L)	DO (mg/L)
Inlet	42.12	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	33.91	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*

Table 2 Correlation matric of water quality in the lake

	pH	EC	NO_3^-	PO_4^{3-}	Fe	DO
pH	1					
EC	-0.137	1				
NO_3^-	**0.628	-0.247	1			
PO_4^{3-}	-0.157	**0.646	-0.148	1		
Fe	-0.042	-0.275	-0.126	-0.186	1	
DO	*0.480	0.036	0.083	-0.221	-0.087	1

*Significant difference at **p<0.01, * p< 0.05*

Correlation matrix between different physical and chemical parameters are shown in Table 2. A correlation matric was observed between some important water quality parameters of the lake, which further indicates the interactions between water chemical constituents. The result showed that, pH had a positive correlation with dissolved oxygen (DO) and nitrate (NO_3^-). According to Battas et al. (2019) pH greatly affects the adsorption rate of nitrate. It also affects the charge on the surface of the adsorbent during the ion exchange process. Also, Electrical conductivity (EC) had a correlation

with phosphate (PO_4^{3-}) because the contamination of inorganic compounds in the solution of phosphate ions contribute to electrical conductivity.

The water quality of the lake can be defined by two indicators such as concentration and load. The concentration indicated in Table 1 and Table 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^- and DO showed a decreasing trend. Iron (Fe) increased 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 (Fig. 2). In contrast to the JICA report, 2016 has stated that the lake has been encroached by houses, factories, agricultural and other activities, and they are no longer effective in performing their natural purification function. The reason could be due to in rainy season the inverse flow direction of water coming from the Mekong River at the southeast part of the lake (outlet), colliding this water moving in the opposite direction (Sovann et al., 2011) pushed the wastewater back to the upper part of the lake which then made the concentration and load of the parameters high in the lake (Nara et al., 2015).

Table 3 Nutrient load at the inlet and outlet

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

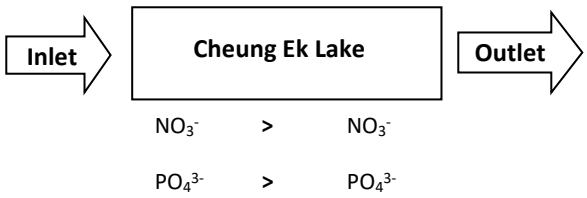

Fig. 2 Function of the Cheung Ek Lake

Socio-Economic Aspects of Water Morning Glory Production

Table 4 shows the socio-economic characteristics of 20 respondents. The average household size was 6.1 people per household, which is higher than the national average of 5.3 people for the urban areas (NIS, 2019). On average, experience in farming water morning glory was 10.4 years and the cultivated area per household was 2.15 ha. The average harvest per day per ha was 164.5 bunch and the average price was 0.37 USD per bunch.

Table 4 Socio-economic characteristics of water morning glory (WG) producers

Number of household (HH)	20.0
Average family size (person)	6.1
Average age of farmer (year)	37.8
Average year of experience in WG production (year)	10.4
Average planted area per HH (ha)	2.15
Average harvest per day per ha (bunch)	164.5
Average price per bunch (USD)	0.37

Source: Field survey, 2019

Total Production Cost and Economic Return of Water Morning Glory

Table 5 showed the result of the production cost (per day/ha) of water morning glory. The result revealed that the total production cost was 29.58 USD per day/ha. The result also showed that most of the expense during the production was on labor.

Table 5 Total production cost of water morning glory

Item	Price (USD)
Total variable cost (a+b)	**28.43**
-Variable cost (a)	**5.85**
Pesticide	3.57
Gasoline	1.55
Plastic	0.22
Boat reparations	0.16
Rope	0.34
-Total labor (b)	**22.58**
Family labor	7.98
Rent labor	14.59

Item	Price (USD)
Total fix cost (c)	**1.15**
Land rent	0.68
Bamboo	0.29
Boat	0.15
Sprayer	0.01
Container	0.01
Total production cost (a+b+c)	**29.58**

Source: Field survey, 2019

Regarding economic return from production, this study examined several indicators, like gross revenue, total cash income and net profit (Table 6). The results show that the gross revenue from the production was 53.35 USD per day/ha (Table 6). The cash income is referring to the income that the farmers received without deducting labor of family involve in the production. In the water morning glory production, the cash income that the farmers received was 32.90 USD per day/ha. Although the farmers spent a lot on labor, the return from the sale was good enough. The economic efficiency for the production was 1.80 (Table 6), suggested that the business with this product is profitable. The value 1.80 of economic efficiency could be interpreted as follows: if 1 USD is spent on the production, 1.80 USD will be received from the sale of products. So, net profit was 0.80 USD per unit of expense.

Table 6 Economic efficiency of water morning glory

Gross revenue (USD)	Cash income (USD)	Net Profit (USD)	Production cost (USD)	Economic Efficiency
53.35	32.90	23.77	29.58	1.80

Figure 3 shows the price chain in water morning glory production between farmers, middlemen, wholesalers and retailers. The price of the water morning glory product varies from month to month according to its availability and demand. The result of the questionnaire survey showed that the price of water morning glory is lower in the dry season compared to the rainy season. The average market price range for farmers and retailers were between 0.22 to1.38 USD per bunch. The difference in the prices can be seen between the first and final supplier.

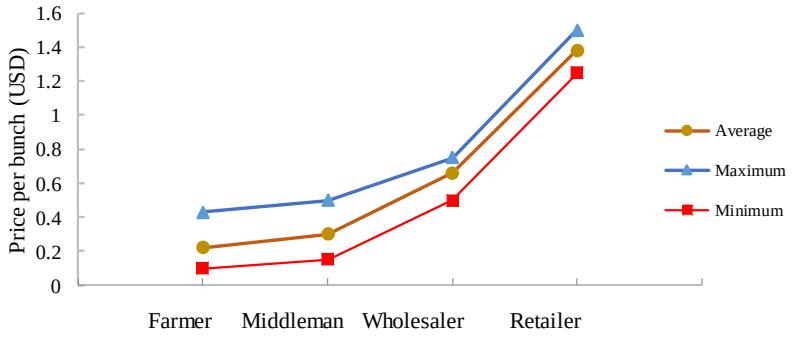

Fig. 3 The price chain in the water morning glory production

Water Quality in Cheung Ek Lake Effect on Economics of Farmers

Cheung Ek Lake plays an essential role in nutrient supply for the farmers during the cultivation of vegetables. According to the questionnaire survey, fertilizer is not necessary for plant production in the lake. Comparing to the amount of fertilizer needed in land cultivation of water morning glory production is around 200-300 kg per hector, costing around 105 $-157 $ in one production cycle. Therefore, the farmers from the lake can earn more by spending less on the extra cost of fertilizer application. However, to think only the benefit, the other point of view also concerning to the quality of the vegetable that product in the wastewater lake.

However, faecal and protozoan parasite contamination were detected in the lake's water morning glory (Anh et al., 2007). According to Van der Hoek et al. (2009), people who were exposed to wastewater at Cheung Ek Lake developed dermatitis. While low concentrations of potential toxic element concentrations were identified in water spinach and fish created in Cheung Ek Lake wastewater systems, indicating that these components pose a minor food safety risk (Marcussen et al., 2009; Chea et al., 2010).

CONCLUSION

Cheung Ek Lake is an important wetland, which used to be an efficient natural treatment plant for wastewater and production of water morning glory in Phnom Penh. In this study, we emphasized on understanding the role of the lake as purify of wastewater. The results on the water quality of the lake indicate that it is becoming less polluted. The result of the chemical load during the rainy season showed that the lake is taking part of purification as well. Nonetheless, the result with the economic analysis from the farmers who cultivated water morning glory in Cheung Ek Lake shows a profitable sign with economic efficiency 1.80.

Overall, Cheung Ek Lake is an essential part of urban ecosystem. This lake performs significant role in removing pollutants from the water and provide economic benefits to the farmers. Additionally, research on the quality during the dry season is required to continue monitoring the lake's water quality. The amount of heavy metal and parasite contamination will also be examined for health assessment.

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