WATER QUALITY MONITORING AND WASTEWATER TREATMENT USING THE CONSTRUCTED WETLAND CONCEPT AT BUNGVA LAKE, KAYSONE PHOMVIHAN CITY, SAVANNAKHET PROVINCE, LAO PDR

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ABSTRACT

This study aimed to monitor physical, chemical, and biological water qualities to design a concept of a horizontal subsurface flow constructed wetland for wastewater treatment. The wetland is a small artificial wastewater treatment system consisting of one or more shallow treatment cells planted with wetland vegetation, which is usually suitable for warmer climates. The Standard Methods for the Examination of Water and Wastewater, 23rd Edition, published in 2017 by APHH, AWWA, and WEF, was used to analyze the ASPT index and water quality parameters. Temperature, pH, electrical conductivity, COD, BOD, and invertebrates were observed at three points at Bungva Lake Basin on March 16, 2021. Based on invertebrates (a water quality indicator), the three points had a water quality index value of 4.4, 3.8, and 3.6, respectively. It was also found that many human activities (agriculture, small industry, and settlement) and geological features control the lake's water quality. Therefore, a horizontal subsurface flow constructed wetland is proposed as sufficient wastewater treatment for the lake.

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INTRODUCTION

Asian wetlands have the highest economic value worldwide due to the high demand for their tangible and intangible products. However, as the global population increases, there is a higher pressure on their biodiversity, scientific, socio-cultural, and aesthetic values, and ecological sustainability (Gland, 2004), threatening their goods and services provision. Besides, wetlands improve water quality, store floodwater, provide habitats for fish and wildlife, and contribute to biological productivity. A value is an estimate of the importance or worth of one or more of the wetland's functions to society. For example, it can be based on revenues generated from the sale of fish that depend on wetlands and tourist visits or public support for fish and

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wildlife protection. Although the large-scale benefits of these functions can be appraised, estimating the value of wetlands separately is difficult as their ecological roles and capacities differ widely.

Lao PDR increasingly recognizes the relevance of wetland resources to livelihoods, biodiversity, and environmental services. The major national significance of the country's wetlands potentially lies in their role as the most important source of protein for the majority of the population. Fish and other aquatic animals account for seventy to ninety percent of the animal protein in people's diets in rural lowlands and highlands.

Bungva Lake is a natural freshwater collector with irreplaceable environmental functions. It is the "cradle" of biological diversity, where countless species of plants and animals depend on its water and primary productivity for survival. Furthermore, with high demand for its goods and services, this swampy lake has various major economic values. However, changes in the climatic system have transformed agricultural practices over the years into using more chemical fertilizer and utilizing the lake intensively, impacting its condition and reducing productivity and biodiversity. Intermittent disruptions such as drought, flood, and chemical influx from agricultural practices are threatening the water quality and livelihood of rural people, who, to many extents, depend on the lake's ability to function for day-to-day subsistence. Therefore, wetland conservation is highly required for the lake's environmental protection and sustainable development. As part of resolving these issues, the study was intended to monitor water quality parameters (physical, chemical, and biological) and employ the concept of a basic-design constructed wetland for wastewater treatment..

MATERIALS AND METHOD

Study Area

Bungva Lake is located in Bungva Village, City of Kaysone Phomvihane, Savannakhet Province. The lake water is 1.15 km2, while, added with the immediate environments as a reservation zone, the area is 2.82 km wide and 0.959 km long. It varies in depth depending on the season: around 1.5 m in dry and 4 m in wet seasons.

There are three villages surrounding and, thus, most influencing the lake: Bungva in the west, Nong Phue in the northwest, and Dong Mak Yang in the northeast, with human settlements, agricultural lands, and forests as the characteristic land use/cover types. Most of the village residents (96.55%) are engaged in agriculture, including 83% farmers and 17% farmworkers. The research area are presented in Figure 1

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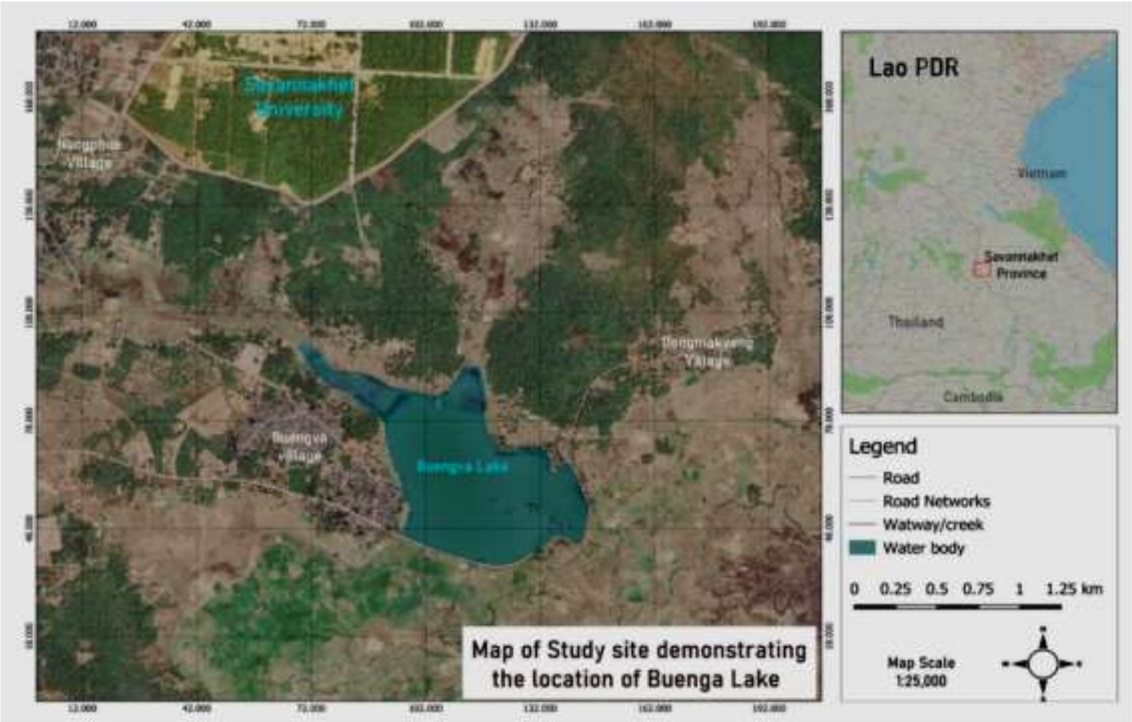

Figure 1. Map of the study area showing the location of Bungva Lake

Methodology

The research data were collected from various water outlets in the morning from two sources of pollution: point-source (domestic wastewater) and non-point-source (broadly distributed sources, not a single discrete source). The physical and chemical parameters evaluated were transparency (Tr), temperature (T), the potential of hydrogen (pH), total dissolved solids (TDS), total phosphorus (TP), dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), and chlorophyll a (Chl a). Temperature, pH, and DO were measured electrometrically in situ using temperature-sensitive electrodes with a Pt-Rh probe coupled with a pH electrode and oxygen meter. Water samples for other physical and chemical parameters were collected in plastic containers, labeled, and transported immediately to the laboratory for tests using the standard

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methods according to APHA (2005) and Trivedy and Goel (1986). Transparency was measured with a Secchi disk, TDS with gravimetry, BOD with titration (after five days of incubation at 20°C), COD with titration (after digestion), and total phosphorus with spectrophotometry (after digestion by ascorbic acid). Chlorophyll a was determined by interpreting the spectrophotometer readings (i.e., absorption) at 660 nm and 620 nm after extraction with 80% acetone.

RESULTS AND DISCUSSION

General information on the population

General information on the population was obtained from the village chief and previous studies. It was later used to estimate population size. There are several methods for estimating population size based on different assumptions or population characteristics. An example is the geometric growth method (EEAT, 2003), which calculates the rate at which populations change from historical data. The result showed a 19% growth rate, with which the future population was projected: 1,881 people in the past (2016), 1,976 people in the present (2021), and 2,147 people in the future (2030). With this information, the research calculated the amount of wastewater generated per day. According to EEAT (1993), the average amount of wastewater produced in a village is 180 liters/day/person. Therefore, based on population projections and the rate of wastewater production, it was found that the study area generated 386.46 liters of wastewater per day—which is a piece of information necessary for designing a horizontal subsurface flow constructed wetland.

Physical, chemical, and biological characteristics

Table 1 shows the direct and laboratory results of the physical, chemical, and biological water qualities at Buengva Lake. The measurement was conducted on March 16, 2021, according to the Standard Methods for the Examination of Water and Wastewater, 23rd Edition, published by APHA, AWWA, and WEF in 2017. Results showed that the pH value, electrical conductivity, ammonium, and coliform of the water samples met the standard. However, DO, TDS, and COD exceeded their maximum permitted levels, indicating regular monitoring is needed.

Table 1. Physical, chemical, and biological water qualities of Bungva Lake based on laboratory test results

No.	Parameter	Measurement Unit	Standard*	Analysis Results
1	Temperature	℃	n'	27
2	Potential of hydrogen (pH)	-	6–8	7.5
3	Electrical conductivity (EC)	µs/cm	≤1,000	580
4	Dissolved oxygen (DO)	mg/L	6	6.4
5	Total dissolved solids (TSS)	mg/L	≤25	40.3
6	Chemical oxygen demand (COD)	mg/L	5–7	60.68
7	Ammonium	mg/L	≤1.5	<0.25
8	Coliforms	MPN/100mL	≤5,000	170

Note: *based on the surface water quality standard, 2017

Wastewater treatment using the principles of constructed wetlands

Figure 2 shows the constructed wetland built in this research to treat raw sewage, stormwater, and agricultural and industrial waste. It mirrors the activities of a natural wetland, including capturing stormwater, reducing nitrogen loads, and creating a diversified animal habitat. In case of seasonal vegetation changes, plants stop growing in autumn, and a gradual decrease in plant count is mainly observed at the end of summer. Since summer is when most nutrient loads come from livestock agriculture, wastewater treatment plants, and stormwater runoffs, a high amount of nutrients was introduced into the constructed wetland system to increase the biomass rate stored in the plant system.

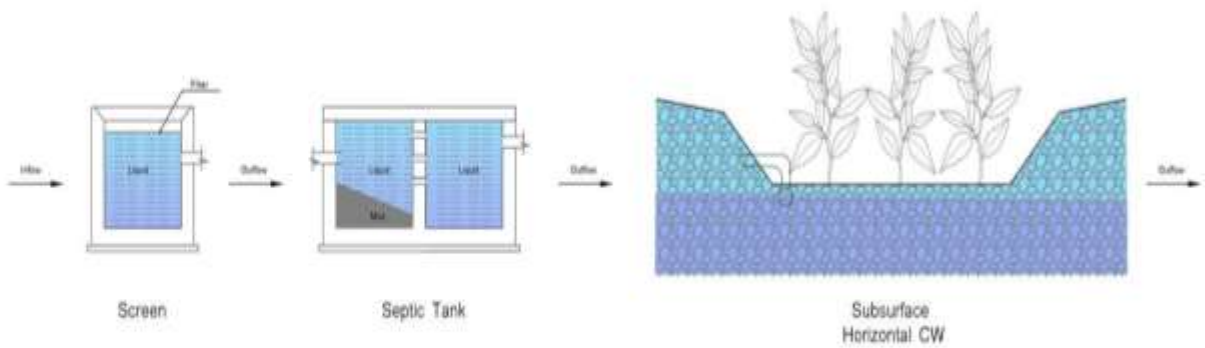

Figure 2 Basic design principles of wastewater treatment

Depending on the zone of Bungva Lake, macrophytes that can grow in the

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constructed wetland are Persicaria decipiens, Blechnum minus, Cyperus lucidus, Vetiveria zizanioides Nash, Bolboschoenus caldwellii, and Juncus ingens. Constructed wetlands must be inspected regularly to ensure they are operating well and in compliance with the approved design and specifications. Items in need of repair must be immediately addressed. The frequency at which a constructed wetland should be maintained depends on the amount of solid waste. However, annual maintenance should at least include removing trash and debris as frequently as possible, checking for and repairing eroded areas, checking for and removing nuisance animals and burrows, inspecting plant composition for consistency with the approved plans, and improving any deficiencies. The wastewater treatment designed in this study included three components: a screen, a septic tank, and a horizontal subsurface flow constructed wetland.

1. Screen

The primary treatment included a physical operation unit to remove floating and suspended solids from the wastewater, called screen. The process itself is termed coarse screening. A screen is the first operation unit in a wastewater treatment plant and can be in the form of a circular or rectangular opening. In this research, the screen was a rack made up of parallel bars or rods. In addition to filtering out larger particles, it protects pumps, valves, pipelines, and other appliances from damage or clogging.

2. Septic tank

A septic tank is the most common primary treatment used worldwide in a small-scale constructed wetland. A two-compartment septic tank can remove more solids than a single one. The middle picture in Figure 1 depicts a schematic cross-section of a typical double-compartment septic tank.

3. Subsurface horizontal flow constructed wetland

This constructed wetland is used for secondary and tertiary treatment of domestic wastewater. In the former, gravel is laid at a depth of 0.5 to 0.7 m, and the water level is kept at 5–10 cm below the surface. In the latter, the basin is 1.0 to 1.5 m deep, and about 0.60 m of it is filled with gravel—which is a design especially used in the UK. The subsurface horizontal flow system in the UK is generally constructed with a longitudinal-sloped base (1%) to facilitate drainage of the bed if needed. The remaining bed volume is used for water storage during high flows or storm events.

CONCLUSIONS

The water quality evaluation of Bungva Lake has found that the physical and chemical parameters meet the criteria set by the environmental standards. On the contrary, the biological parameter value measured using invertebrates at the three observation points exceeds its maximum allowable level. Due to the increasing population, water consumption, and wastewater production, determining a place and system to receive and treat wastewater before releasing the treated wastewater into the reservoir is highly recommended.

Pollution is removed through the processes commonly occurring in natural wetlands, but in a constructed wetland, they proceed under controlled conditions. All types of constructed wetlands are very effective in removing organics and suspended solids. Although they have low performance in removing nitrogen, this can be enhanced by combining various types of constructed wetlands. In addition to treatment, they are often designed as a dual- or multipurpose ecosystem, which may provide other ecosystem services such as flood control, carbon sequestration, or wildlife habitat

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