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Waste stabilization pond design for wastewater treatment at Huakhua village, Xaysettha district, vientiane capital

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Article Info	ABSTRACT
Keywords: BOD, COD, Stabilization ponds, TKN, TSS	The objective of this study is to design on waste stabilization pond model and evaluate the treatment efficiency of system by Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD5), Total Kjeldahl Nitrogen (TKN), Total Suspended Solid (TSS), Temperature (T) and Turbidity, the system includes an anaerobic, facultative and maturation ponds that is used to treat waste water and water samples is collected from 4 different sites and also 3 different times of water samples, then mixed them before adding to the system, the initial concentration of T(27.3±1.93C), pH (8.85±0.23), Turbidity (9.73±0.57 NTU), TSS (8.33±2.52 mg/l), BOD5(11.67±1.26 mg/l), COD (24.88±3.81mg/l) and TKN(0.98±0.99mg/l, in addition, the experiment took 45 days to monitor the waste water in the stabilization ponds and 5 days of detention time of sampling water to test, consequently, the results revealed that, the treatment efficiency at maturation pond of effluent values of each parameter varies from 73 to 99 %, there are T (0.47%), pH (20.74%), turbidity (82.10%), TSS (79.68%), BOD5(73.88 %), COD (75.27%) and TKN (86.54%).
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INTRODUCTION

Waste Stabilization Pond(WSP) is method of using biological treatment(Mara, 2006) and commonly used in the cities, communities and villages with large area and limited cost to operate and maintain (Verbyla et al., 2016), wastewater treatment is very significant process to treat to reduce pollutant contamination (Siharath, Sonemanivong, et al., 2023) and also promote to protect environmental heaths and ecosystem prior to discharging to environment(Siharath, Vilaychaleun, et al., 2023; Yahya et al., 2020). The system consists of three ponds such as anaerobic, facultative and maturation ponds, hence, the anaerobic pond is primary treatment, it is designed in order to reduce organic load and avoid the risk of order release because of hydrogen Sulfide gas (H_2S)(Olukanni, 2011), Facultative Pond is designed for BOD_5 removal on the basis of a low organic surface load achieved by anaerobic pond to permit the development of an active algal population. This way, algae generate the oxygen needed to remove soluble BOD_5 (Hodgson, 2007; Mkude et al., 2014), and maturation pond is tertiary treatment and classically designed for excreted pathogen removal(Mumtaz & Hashim, 2012; Utsev & Agunwamba, 2012).

METHODS

Study Location

Wastewaters samples were collected at Huakhua village where wastewater mainly comes from two sources such as Thatluang marsh and Hongkea canal within Xaysetha district, Vientiane Capital, depicted in Figure1, the majority of wastewater is discharging from households, offices, markets, industrial business, shops and also restaurant and lack of wastewater treatment system(Kyophilavong, 2008), most of wastewater will flow to Houay Mak Hiao Stream and falls into Mekong River(Kolehmainen & Axén, 2013). Therefore, the WSP physical model was made to examine wastewater quality and closely trace at Chemical Engineering Department, Faculty of Engineering, National University Laos as indicated in Figure2.

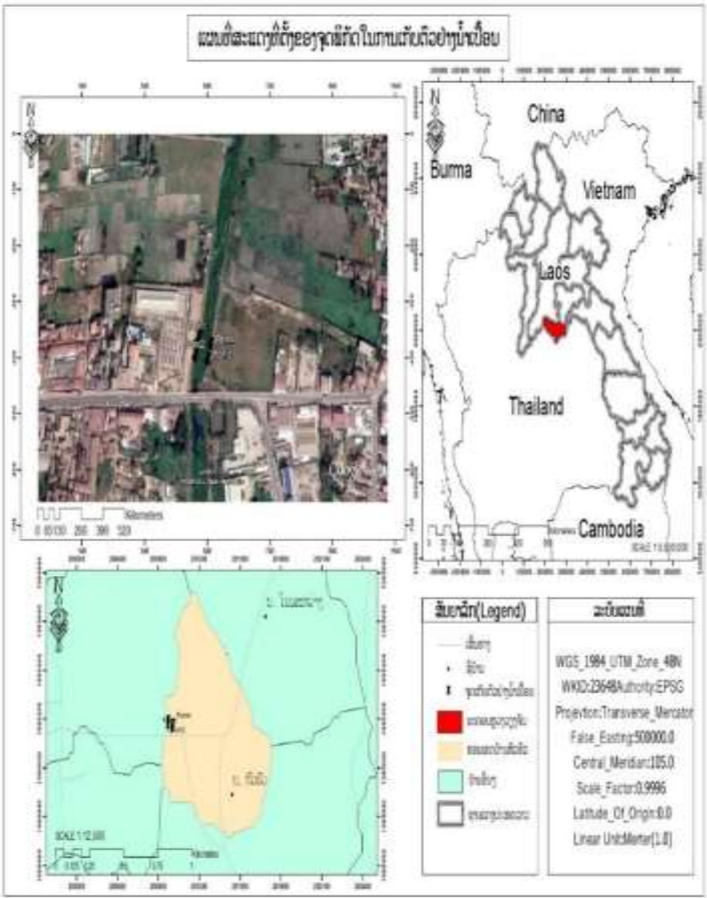

Figure 1. Study site in Vientiane Capital Map

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Waste Stabilization Pond model design

The system is designed and constructed typically in order to treat wastewater, in particular, decrease the organic content or get rid of pathogen in wastewater(Ho et al., 2017), essentially, the system includes three components such: aerobic pond (Influent), Facultative Pond and Maturation Pond (Effluent) (Marais, 1966; Siharath, Xayyamunh, et al., 2023) as illustrated in Figure2.

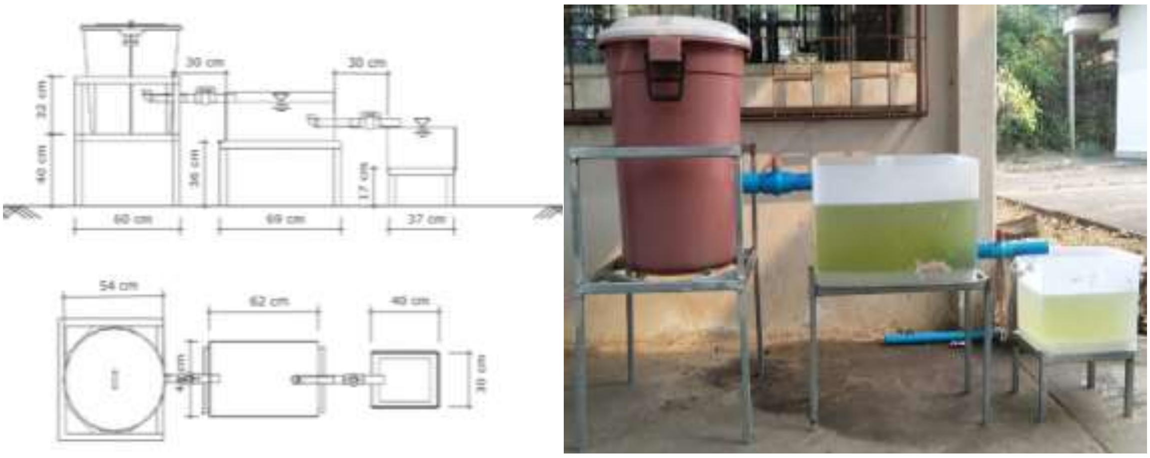


Figure 2: Waste Stabilization Pond physical model

Anaerobic Pond treatment physical model design

Anaerobic is designed for removal of biochemical oxygen demand (BOD) and without oxygen (Bansah & Suglo, 2016), this pond is designed with dimension of height (60 cm), width (top: 54 cm and bottom: 44 cm), this pond will be received waste water as influent, indicated in Figure 3.

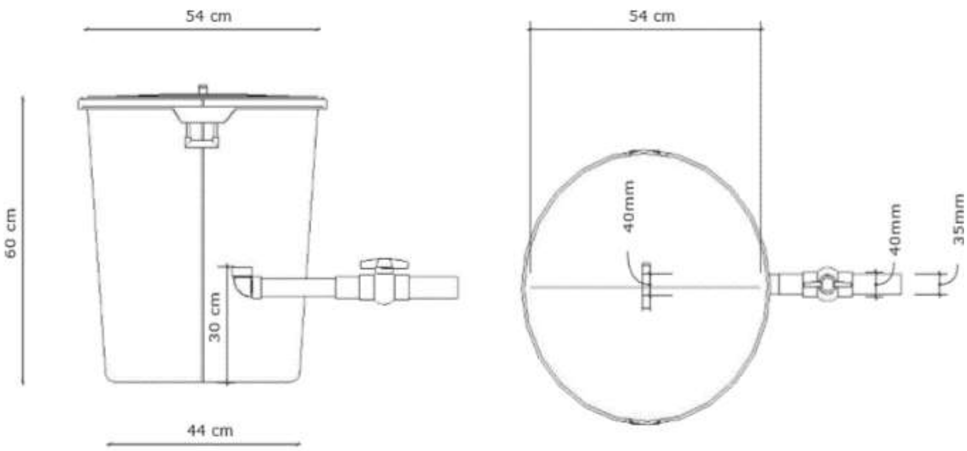
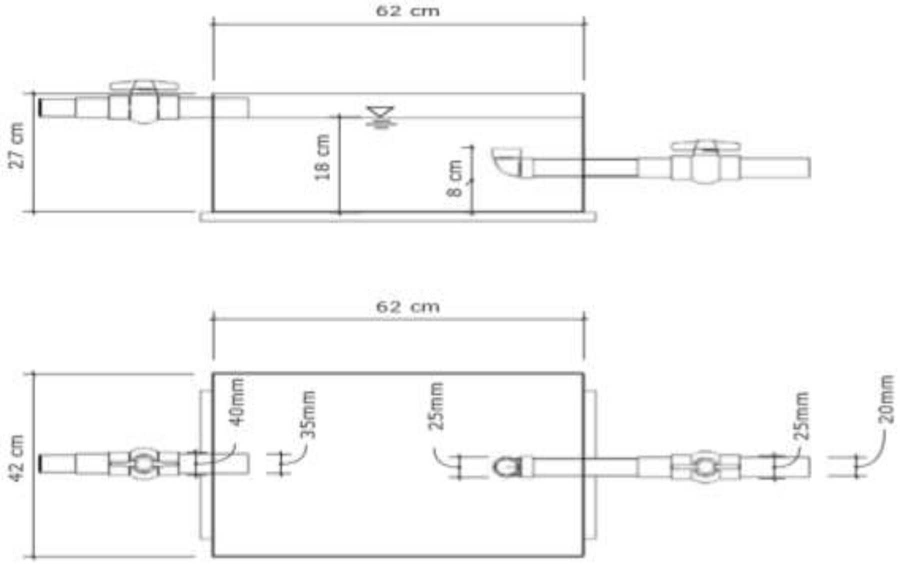


Figure 3: Anaerobic Pond treatment physical model design

Facultative Pond treatment physical model design

Facultative ponds, in which the upper and lower layers are aerobic and anaerobic, respectively; this type includes most of the ponds generally described as oxidation ponds and it is designed for BOD removal(Egwuonwu et al., 2014; Nanayakkara, 2013). this pond is designed with dimension of height (27 cm), width (42 cm) and length(62cm), this pond will be received waste water from the anerobic pond as indicated in Figure4.



'**Figure 4:** Facultative Pond treatment physical model design

Maturation Pond treatment physical model design

Maturation ponds, for treating effluents from conventional disposal works(Ali, 2000; Hayati et al., 2013), dimension of this pond is length (40 cm), width(30 cm) and height(22 cm).

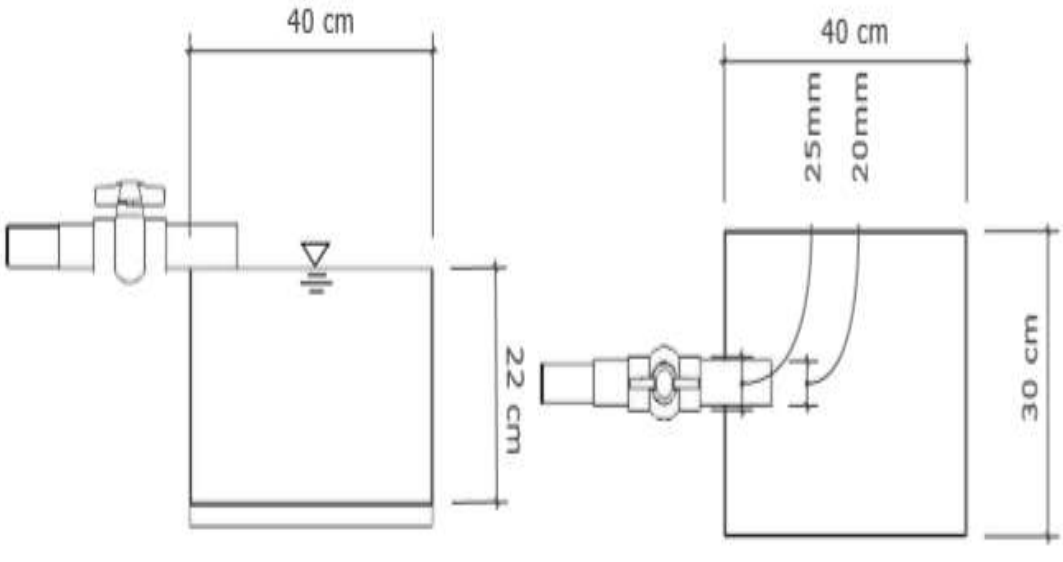


Figure 5: Maturation Pond treatment physical model design

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THE WATER QUALITY ASSESSMENT

- The aerobic pond's volume

Formula: $V_{total} = \frac{1}{3} h \left(A_1 + A_2 - \sqrt{A_1 A_2}\right)$ .... (a)

Where V_{total} : The amount of sewage in an aerobic pond (L)
A_1: Floor of the aerobic pond (m^2)
A_2: A portion of the aerobic pond (m^2)

- The flow rate algorithm

Formula: $Q_i = V_i/t_i$ .... (b)

Where Q: flow rate (L/s),
V: volume (L)
t: flow time (s)
i: Facultative, maturatione Pond

- The Facultative and maturatione Pond 's volume.

Formula: $V_i = A_i \times h_i$ .... (c)

Where V: The Facultative Pond 's volume(m^3)
A: The area Pond (m^2)
h: height(m)
i: Facultative, maturatione Pond

Chemical Oxygen Demand (COD)

Formula: COD= (A-B) xNx80/V .... (d)

A: Total solute volume FAS which is combined with titrated Blank, (ml)
B: Total solute volume FAS which the sample is used to titrate, (ml)
N: Concentration of a solute FAS, (N)
V: Volume of the Sample of Wastewater, (ml)

Biochemical Oxygen Demand (BOD)

Formula: $BOD_5 = DO_0 - DO_5$ (mg/l) .... (e)

DO_0: Day one of dissolved oxygen, (mg/l)
DO_5: On the fifth day after incubation at 20 °C, there was dissolved oxygen, (mg/l)

Total Kjeldahl Nitrogen (TKN)

Formula: TKN= (A-B) x280/V .... (f)

A: Volume of 0,025 H_2SO_4, which the sample is used to titrate, (ml)
B: Volume of 0.025 H_2SO_4 , which is combined with titrated Blank, (ml)
V: Volume of the Sample of Wastewater, (ml)

TSS: Total Soluble Solid (TSS)

Formula: TSS = (A -B) x 1000/C ....(g)

TSS: Total Suspended Solids content, (mg/l)

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A: Weight of the tissue paper, (mg)
B: Weight of suspended solids and fiberglass filter paper, (mg)
C: Utilized sample water volume, (mg)

Waste Stabilization pond efficiency(η)

$$\eta = \frac{(C_1 - C_2)}{C_1} \times \mathbf{100}\% \quad \text{........(h)}$$

η: Waste Stabilization pond efficiency, (%)
C_1: Effluent concentration, (mg/l) \
C_2: Discharge concentration, (mg/l)

RESULTS AND DISCUSSION

Wastewater samples were contained and treated by the waste stabilization model as illustrated in Figure 2 and evaluated based on the formula (a, b and c) at Aerobic Pond is 110L, Facultative Pond is 70L, and Maturation Pond is 26L. Hence, the effluent of wastewater is measured and calculated at Aerobic, Facultative, and Maturation Pond, the influent are 110L/5 days(22L/day), 70L/5 days(14L7day) and 26L/5 days(5.2L7day) and effluent are 55L/5 days(11L/day), 50L/5 days(10L/day) and 13L/5 days(2.6L/day), respectively, then the flow rates were assessed at Aerobic Pond (1L/day), Facultative Pond (0.33L/day), and Maturation Pond (NA), the detention time of experiment is fixed on every 5 days taking the water samples from the waste stabilization to test for water quality of each ponds as indicated in Table1.

Table1: Work performance of waste stabilization pond system

Description	Aerobic pond	Facultative pond	Maturation pond
Detention time	5 days	5 days	5 days
Wastewater volume (L)	110 L	70L	26L
Influence (L/day)	110L/5 days	70L/5days	26L/5 days
Effluent (L/day)	55L/5 days	20L/5 days	13L/5 days
Water sample (time/day)	3times/5 days	3times/5 days	3times/5 days
Flow rate(L/s)	1L/s	0.33L/s	NA

Based on the exiting waste stabilization pond model and method design, wastewaters samples were collected in 3 different time and also 4 locations, water quality was conducted and tested, therefore, the water quality concentration of each pond is calculated and applied standard deviation to differ the chemical parameter as showed in Table 1.

Table 2: Results of the wastewater treatment in the waste stabilization pond model

No	Parameter	Unit	Wastewater	Waste Stabilization Pond		
				Anaerobic pond	Facultative pond	Maturation pond
01	Temperature	°C	27.4±1.93	25.2 ±0.66	27.17±1.50	27.3±1.93
02	pH		7.33±0.76	6.87±0.75	8.58±0.57	8.85±0.23
03	Turbidity	NTU	54.37±4.49	33.28±5.48	9.88±0.94	9.73±0.57

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No	Parameter		Waste Stabilization Pond			
04	TSS	mg/L	41.0±4.58	22.0±10.0	16.5±3.97	8.33±2.52
05	BOD_5	mg/L	44.67±6.79	15.47±0.95	12.83±0.76	11.67±1.26
06	COD	mg/L	100.6±4.93	25.45±1.78	27.67±0.58	24.88±3.81
07	TKN	mg/L	7.28±0.28	4.20±2.67	1.31±0.90	0.98±0.99

Initial concentration of the water quality was examined and found that

Due to the wastewater are from various sources within Vientiane Capital and untreated prior to discharging to Thatluang marsh and Hongkea cana , consequently, based on the results of water quality experiment shows that there are some chemical parameters are deemed to high concentration for instance: Turbidity (54.37±4.49 NTU), TSS (41.0±4.58 mg/l), BOD_5(44.67±6.79 mg/l), COD (100.6±4.93/l) and TKN (7.28±0.28 mg/l), nevertheless, the T(27.4±1.93°C) and pH (7.33±0.76) are neutral condition as showed in Table1, therefore, the most significant highest concentration is COD, the second is turbidity and third is BOD_5.

Anearobic pond treatment

The treatment was conducted and monitored within 45 days, as indicated in Table2, Figure 6 and Figure 9, the parameters show: T(25.2 ±0.66°C),pH(6.87±0.75), turbidity (33.28±5.48 NTU), TSS (22.0±10.0 mg/l), BOD_5(15.47±0.95 mg/l), COD (25.45±1.78 mg/l) and TKN (4.20±2.67 mg/l) are reduced gradually, therefore, when comparing between the initial concentration and concentration at this pond, the treatment efficiency of each parameter are: T(8.13%),pH(6.28%), turbidity (38.79%), TSS (46.34%), BOD_5(65.37%), COD (74.7%) and TKN (42.31%). Therefore, the most significant effectiveness of highest reduction is COD, second is BOD_5 and third reduction is TSS, because of the microorganism is degrade organic and inorganic in wastewater and re-act to the suspended solid to be settled. Nevertheless, some kinds of suspended solid is not able to degrade by microorganism within 5 days due to their complex chemical structures and then microorganism can be dead during these 5 days (Endogenous Growth Phase)(Abbassi et al., 2016).

Facultative pond treatment

After treatment within 45 days, the parameters show in Table2, Figure 7 and Figure 9 that values of the T(27.17±1.50°C), pH (8.58±0.57), Turbidity (9.88±0.94 NTU), TSS (16.5±3.97 mg/l), BOD_5(12.83±0.76 mg/l), COD (27.67±0.58 mg/l) and TKN(1.31±0.90mg/l) are decreased slowly, consequently, when comparing between the initial concentration and concentration at this pond, the treatment efficiency of each parameter are: T(0.95%),pH(17.05%), turbidity (81.83%), TSS (59.76%), BOD_5(74.28%), COD (72.5%) and TKN (82.01%).Hence, the most significant effectiveness of highest reduction is TKN, second is turbidity and third reduction is BOD_5, because of the oxygen is generated due to algae-mediated photosynthesis, at the bottom of the pond has some sediments and dead baterias is settled and re-action of organic degradation and new organic will be occurred for instance: NO_2,CO_2, NH_3,CH_4 and H_2S(dos Santos & van Haandel, 2021; Menya et al., 2013; Okonofua & Oghoyafedo, 2019).

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Maturation pond treatment

Within 45 days, that water quality was conducted and observed in the waste stabilization pond, the parameters are presented that T(27.3±1.93°C), pH (8.85±0.23), Turbidity (9.73±0.57 NTU), TSS (8.33±2.52 mg/l), BOD_5(11.67±1.26 mg/l), COD (24.88±3.81mg/l) and TKN(0.98±0.99mg/l) are diminished moderately as indicated in Figure 8 and Figure 9, Hence, when comparing between the initial concentration and concentration at this pond, the treatment efficiency of each parameter are: T(0.47%),pH(20.74%), turbidity (82.10%), TSS (79.68%), BOD_5(73.88%), COD (75.27%) and TKN (86.54%). Consequently, the most significant effectiveness of highest removal is TKN, second and third reduction are turbidity and TSS, respectively. Due to the pond is removal of faecal indicator bacteria and pathogenic bacteri, NH_3, concentration (Chikwue et al., 2015; Mtethiwa et al., 2008; Shillinglaw & Pieterse, 1977).

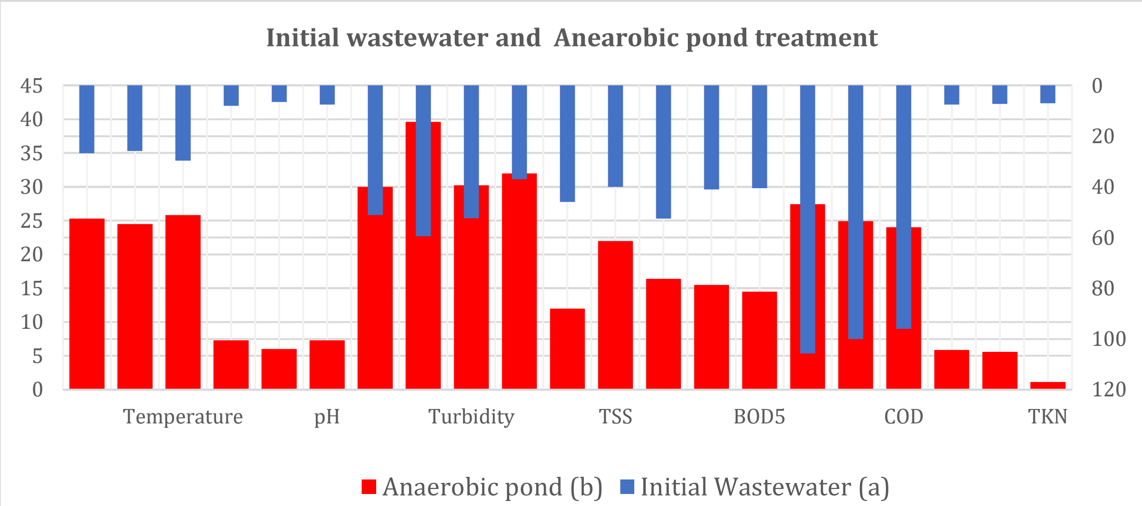

Figure 6: Initial concentration and water quality at Anaerobic Pond comparison

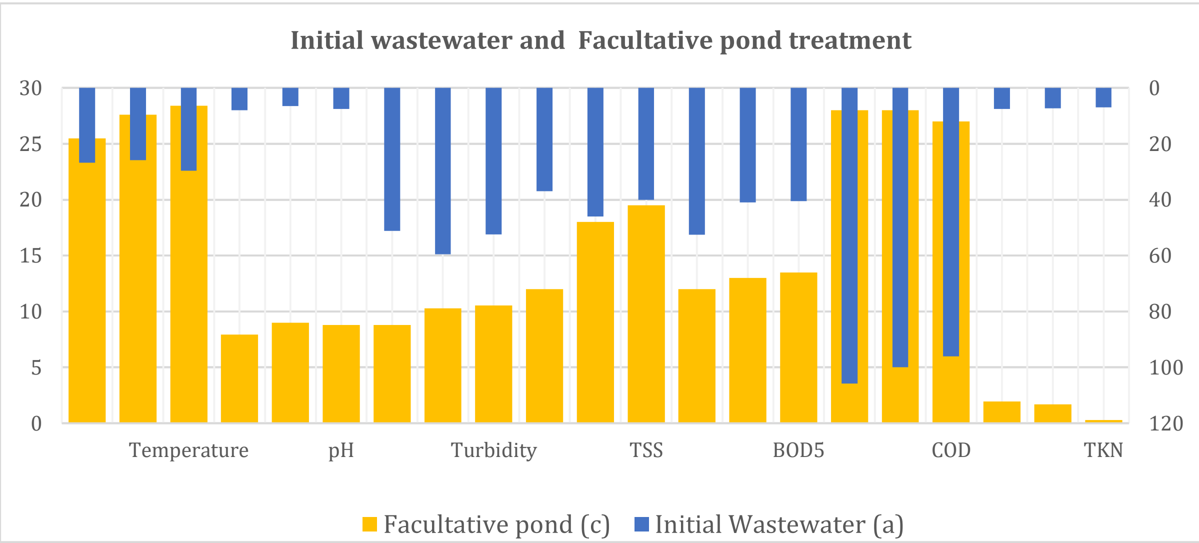

Figure 7: Initial concentration and water quality at facultative Pond comparison

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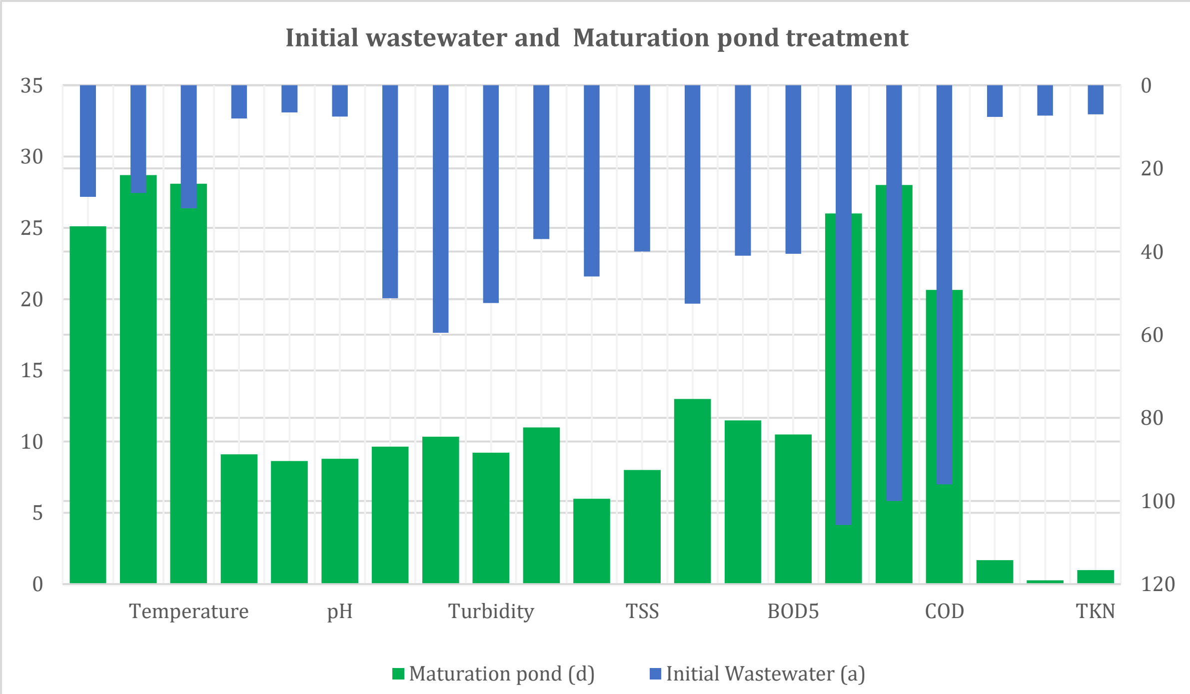

Figure 8: Initial concentration and water quality at maturation Pond comparison

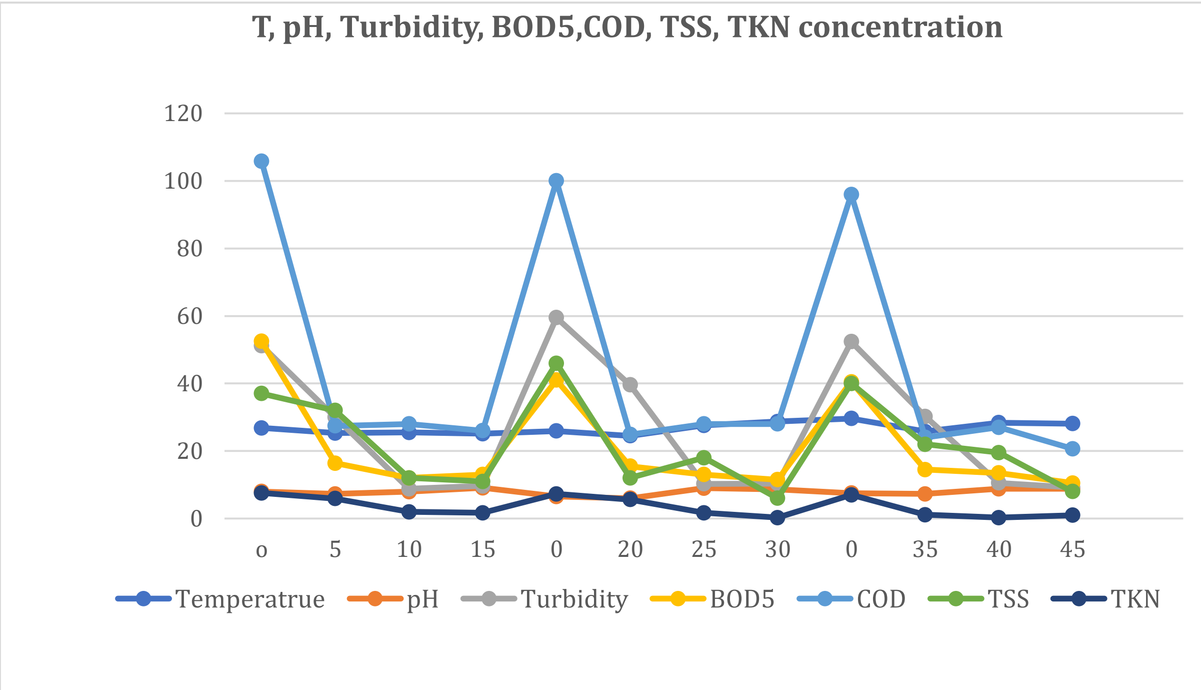

Figure 9: T, pH, Turbidity, BOD5, COD, TSS, TKN concentration within 45 days

CONCLUSIONS

Based on the study, it is able to summarize that, the waste stabilization pond system performed and treated wastewater quite well, the finding of study found that treatment efficiency of wastewater at maturation pond, are T (0.47%), pH (20.74%), turbidity (82.10%), TSS (79.68%), BOD_5(73.88%), COD (75.27%) and TKN (86.54%). Obviously, the quality of the final effluent was indicated to be satisfactory and would not have any serious potential health hazard on environment, in addition, the waste stabilization pond system provides a very useful and appropriate method of wastewater treatment, prior to discharging untreated wastewater from communities, therefore, it should be regarded as a method of choice for treating wastewater in order to prevent and sustainable environmental health and less pollution to water.

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