Asian Journal of
Science, Technology, Engineering, and Art

e-ISSN : 3025-4507
p-ISSN : 3025-5287

Index : Harvard, Boston, Sydney University, Dimensions, Lens, Scilit, Semantic, Google, etc

https://doi.org/10.58578/AJSTEA.v2i2.2797

# BIOCHEMICAL OXYGEN DEMAND MODELING IN WASTE STABILIZATION POND MODEL

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**Article Info:**

| Submitted: | Revised: | Accepted: | Published: |
|---|---|---|---|
| Feb 20, 2024 | Mar 7, 2024 | Mar 10, 2024 | Mar 13, 2024 |

**Abstract**

The objective of the study is to optimize the kinetic reaction value and model the Biochemical Oxygen Demand ($BOD_5$) on remaining and removal in the waste stabilization pond model, therefore, the waste stabilization pond system includes an anaerobic, facultative and maturation ponds, the study are employed the initial concentration of $BOD_5$ (44.67±6.79 mg/l) from the wastewater sources at Huakhua village, Xaysettha District, Vientiane Capital, additionally, the evaluation are conducted in 3 hydraulic schemes that includes: plug flow, complete mix(single cell) and complete mixed (equal cells in series), consequently, according to the results found that: kinetic reaction values is 0.49 $d^{-1}$ and the coefficient of determination ($R^2$) are 0.99, 0.95 and 0.98, respectively.

**Keywords**: Anaerobic, $BOD_5$ , Facultative, Kinetic Reaction, Maturation

## INTRODUCTION

Currently, Waste Stabilization Pond(WSP) is common method to treat waste water by natural based solution with biological treatment(Islami, et al. , 2022) and also popular to employs in the urban, large communities to improve water quality (Sunarsih Sunarsih, 2018), wastewater treatment is very crucial process to reduce high concentration of pollutant contamination in water and conserve sustainable water and ecosystem (Siharath, Sonemanivong, et al. , 2023; Siwiec, et al. , 2011), The WSP system includes an anaerobic, facultative and maturation ponds(Siharath, et al. , 2024). Therefore, Biochemical Oxygen Demand (BOD) is a vital parameter to indicate the requirement of oxygen in water (Ogarekpe, et al. , 2012), BOD is a measure of the dissolved oxygen consumed by microorganisms(Gitta Agnes, et al. , 2017; Mekaoussi, et al. , 2023; S Sunarsih, et al. , 2020) during the oxidation of reduced substances in waters and wastes(Shekarabi, 2023; Siharath, Vilaychaleun, Thammathevo, Sonemanivong, Kannitha, Nhaovarath, et al. , 2023), the use of mathematical models describing wastewater treatment is taken into consideration. the BOD concentrations were used in the first order kinetics parameters(Shekarabi, 2023) (ultimate BOD and BOD reaction rate constant) determination using various methods(Khusravi, et al. , 2013; Mazumder & Bhaduri, 2020; Oke, et al. , 2016; Siharath, Vilaychaleun, Thammathevo, Sonemanivong, Kannitha, Phommakone, et al. , 2023).

## METHODS

### Waste Stabilization Pond model

The WSP system is set up to model and treat wastewater(Siharath, Xayyamunh, et al. , 2023), to reduce and minimize the organic content or gets rid of pathogen in wastewater(Adibe & Ugwuanyi, 2019; S Sunarsih, et al. , 2021), in particular, the system includes 3 components such: aerobic pond , facultative ond and maturation pond as depicted in Figure1.

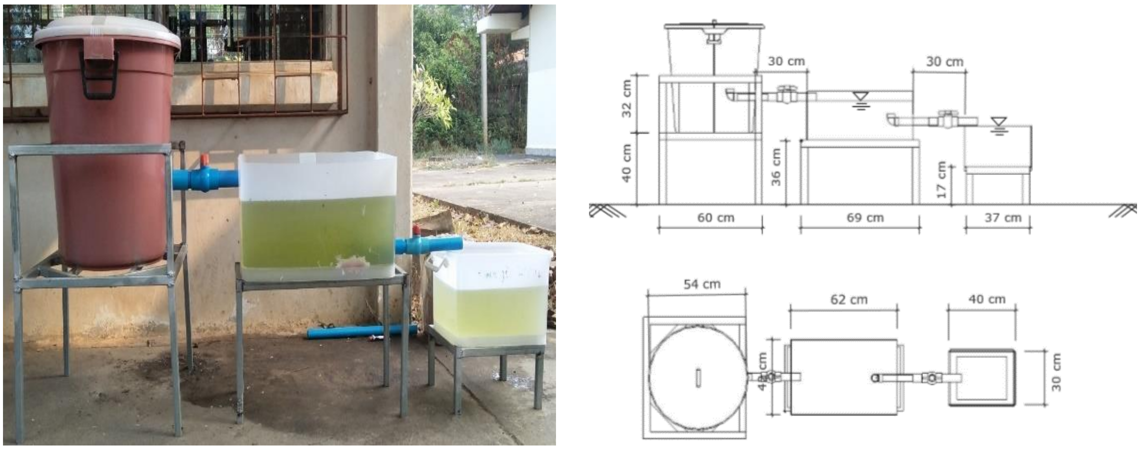


**Figure 1: Waste Stabilization Pond Model**

**Table1:** Results of the wastewater treatment in the waste stabilization pond model(Siharath, et al. , 2024)

| No | Parameter | Unit | Waste Stabilization Pond | | | |
|---|---|---|---|---|---|---|
| | | | Wastewater | Anaerobic pond | Facultative pond | Maturation pond |
| 01 | $BOD_5$ | mg/L | 44.67±6.79 | 15.47±0.95 | 12.83±0.76 | 11.67±1.26 |

**BOD modelling and Equations**

The study is employed formulas to evaluate and calibrate the BOD concentration of remaining and removal in the hydraulic regime(Alavi, et al. , 2022; Ammary, et al. , 2014; Sunarsih Sunarsih, et al. , 2021; Von Sperling, 2007) as below:

1.Plugflow scheme $$s = s_0 e^{-Kt} \quad \text{(i)}$$

2.Complete mix (Single cell) $$s = \frac{s_0}{1+Kt} \quad \text{(ii)}$$

3.Complete mixed (equal cells in series) $$s = \frac{s_0}{(1+\frac{Kt}{n})^n} \quad \text{(iii)}$$

Where:

$s_0$: Total influent BOD concentration (mg/l)

s: Soluble effuent BOD concentration (mg/l)

K: BOD removal coefficient ($d^{-1}$)

t: Total detention time in the system (d)

n: Number of series pond in series

$$4.R^2 = \frac{\sum_{i=1}^{n}(BOD_{pred,i}-\overline{BOD_{pred}})(BOD_{obs,i}-\overline{BOD_{obs}})}{\sqrt{\sum_{i=1}^{n}(BOD_{pred,i}-\overline{BOD_{pred}})^2 \sum_{i=1}^{n}(BOD_{obs,i}-\overline{BOD_{obs}})^2}} \quad \text{(iv)}$$

$$5.RMSE = \frac{\sum_{i=1}^{n}(BOD_{pred,i})^2}{\sum_{i=1}^{n}(BOD_{pred})^2} \quad \text{(v)}$$

Where:

$R^2$: Coefficient of determination

RMSE: Root mean square error

$BOD_{pred}$: BOD prediction in the model(mg/l)

$BOD_{obs}$: BOD observation in the model(mg/l)

$\overline{BOD_{pred}}$: The mean of BOD prediction in the model(mg/l)

$\overline{BOD_{obs}}$: The mean of BOD observation in the model(mg/l)

n: number of observation

$$6.\eta = \frac{(BOD_1-BOD_2)}{BOD_1} \times 100\% \quad \text{(vi)}$$

Where:

$\eta$: Waste Stabilization pond efficiency, (%)

$BOD_1$: Effluent concentration, (mg/l)

$BOD_2$: Discharge concentration, (mg/l)

## RESULTS AND DISCUSSION

The Kinetic reaction was set, the ranges are 0.09- 0.7 $d^{-1}$, they were conducted with trial-and-error values in the model, based on the equation employment(i, ii and iii)(Islami, et al. , 2022; Pattnaik, et al. , 2021; Von Sperling, et al. , 2020), consequently, it was calibrated and found that the optimized value of kinetic reaction value is 0.49 $d^{-1}$ and finally, the RMSEs in the model (RMSE1(plug flow), RMSE2(complete mix (single cell)) and RMSE3(complete mixed (Equal cells in series)) are found that 7.87 mg/l, 5.065 mg/l and 6.88 mg/l, respectively, as indicated in Table2.

**Table 2:** Kinetic reaction and Root mean square error relationship in Waste Stabilization Pond

| Run | Kinetic reaction($d^{-1}$) | RMSE1(mg/l) | RMSE2(mg/l) | RMSE3(mg/l) |
|---|---|---|---|---|
| 1 | 0.09 | 4.6554 | 6.223703 | 5.160349 |
| 2 | 0.11 | 3.9224 | 5.307795 | 4.2451 |
| 3 | 0.13 | 3.6483 | 4.601216 | 3.667982 |
| 4 | 0.16 | 3.7983 | 3.859476 | 3.330783 |
| 5 | 0.19 | 4.2410 | 3.43259 | 3.432859 |
| 6 | 0.22 | 4.7460 | 3.256308 | 3.754704 |
| 7 | 0.25 | 5.2326 | 3.263965 | 4.156487 |
| 8 | 0.28 | 5.6790 | 3.392058 | 4.571925 |
| 9 | 0.31 | 6.0835 | 3.590572 | 4.973862 |
| 10 | 0.34 | 6.4500 | 3.825731 | 5.352589 |
| 11 | 0.37 | 6.7835 | 4.076785 | 5.705777 |
| 12 | 0.4 | 7.0890 | 4.331642 | 6.034123 |
| 13 | 0.43 | 7.3705 | 4.5835 | 6.33946 |
| 14 | 0.46 | 7.6317 | 4.828668 | 6.623943 |
| **15** | **0.49** | **7.8752** | **5.065268** | **6.889697** |
| 16 | 0.52 | 8.1035 | 5.292472 | 7.138686 |
| 17 | 0.55 | 8.3186 | 5.510057 | 7.372658 |
| 18 | 0.58 | 8.5221 | 5.718143 | 7.593155 |
| 19 | 0.61 | 8.7154 | 5.917043 | 7.801517 |
| 20 | 0.64 | 8.8995 | 6.107165 | 7.998913 |
| 21 | 0.67 | 9.0755 | 6.288963 | 8.186359 |
| 22 | 0.7 | 9.2441 | 6.462903 | 8.364738 |

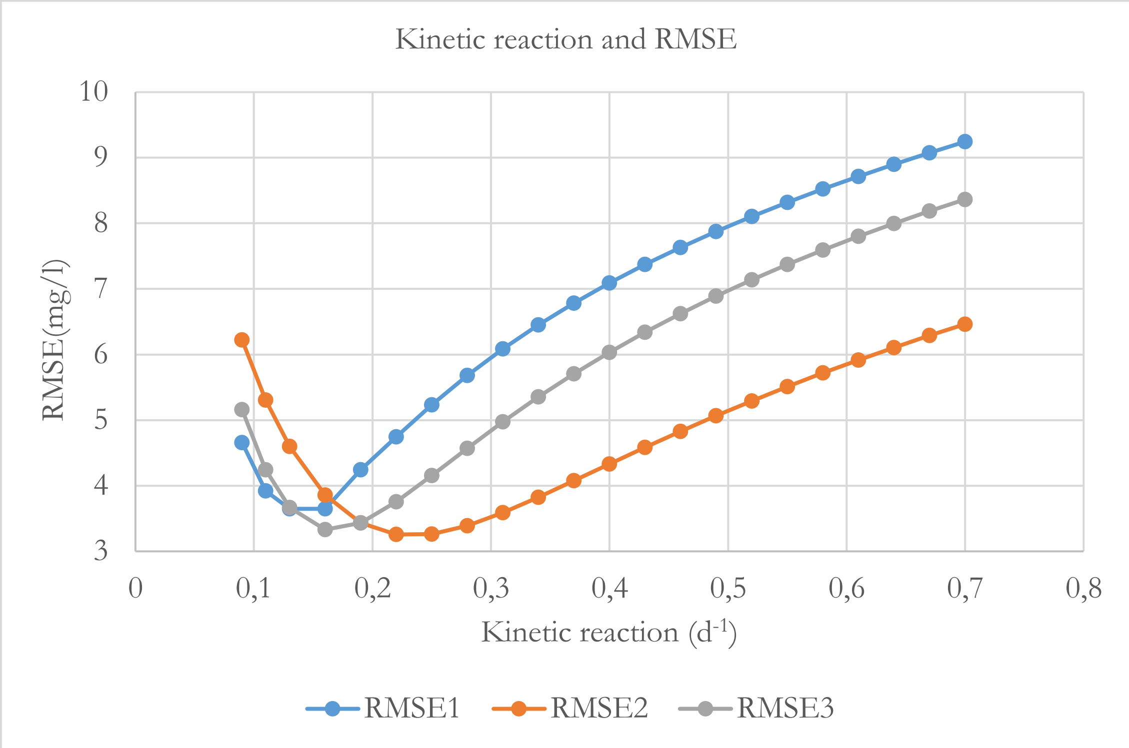


**Figure 2: Kinetic reaction and Root mean square error relationship**

The Plug flow model indicates that the RMSE1 concentrations are ranged from 6.633±1.898 mg/l as shows in Figure2, when the kinetic reactions are between 0.9-0.13 $d^{-1}$, RMSE1s are declined between 4.6554 mg/l -3.6483 mg/l, and the kinetic reactions are greater than 0.13 $d^{-1}$, the RMSE1s are increasing from 3.6483 mg/l to 9.2441 mg/l, simultaneously, Figure3 depicts that the $BOD_5$ remaining and removal are fitted in the model of plug flow with appropriated Coefficient of determination is 0.99.

Figure4 illustrates the $BOD_5$ remaining and removed concentration in plug flow hydraulic regime, in anaerobic pond, facultative pond and maturation pond:

- At day 5 the remaining concentrations are 7.36 mg/l, 5.39 mg/l and 5.84, mg/l, during this period, the removed concentrations are 9.03 mg/l, 6.609 mg/l 7.1599 mg/l, respectively.
- At day 10 the remaining concentrations are 3.309 mg/l, 2.42 mg/l and 2.623 mg/l, in the meantime, the removed concentrations are 13.09 mg/l, 9.578 mg/l, 10.376 mg/l, respectively.

- At day 15 the remaining concentrations are 1.486 mg/l, 1.0879 mg/l and 1.17858 mg/l, in this period, the removed concentrations are 14.0139 mg/l. 14.913 mg/l, 10.912 mg/l and 11.82 mg/l, respectively.
- At day 30 the remaining concentrations are 0.134 mg/l, 0.0986 mg/l and 0.1068 mg/concurrently, the removed concentrations are 16.26 mg/l, 11.901 mg/l and 12.893 mg/l and, respectively.
- At day 60 the remaining concentrations are 0.0011 mg/l, 0.0008 mg/l, 0.00087 mg/l, simultaneously, the removed concentrations are 16.398 mg/l. 11.999 mg/l and 12.999 mg/l, respectively.

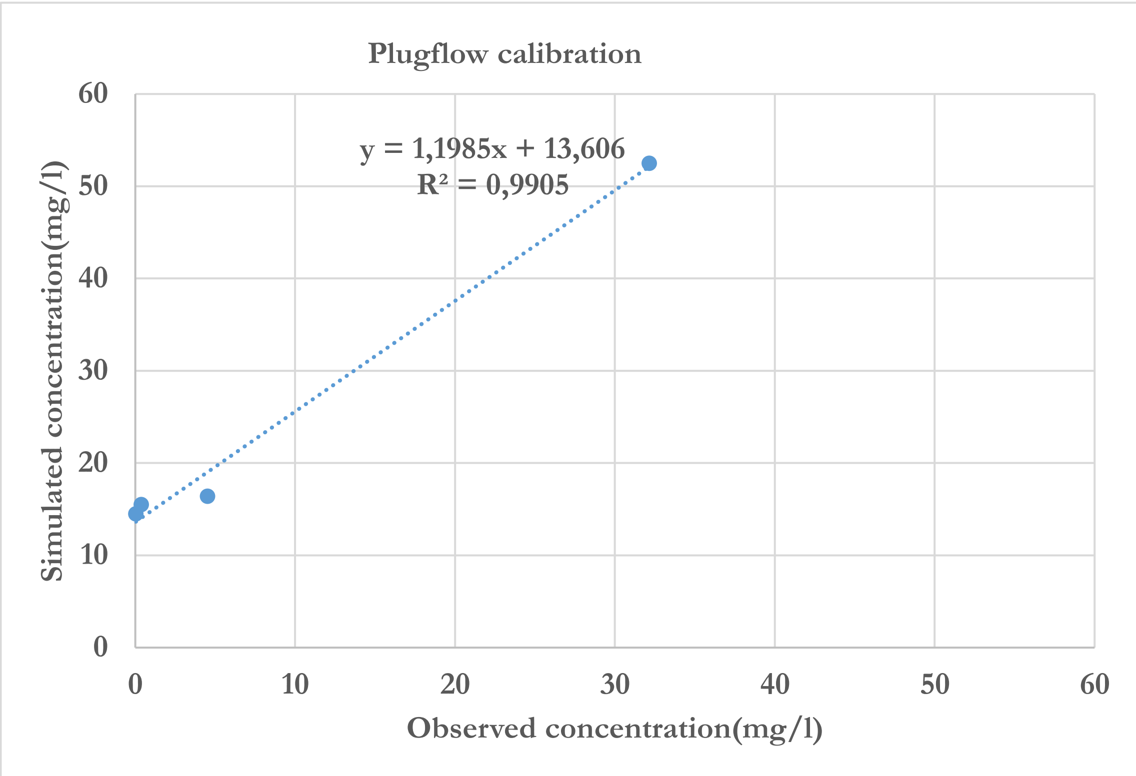


**Figure 3: Observed and simulated concentration in Plug flow**

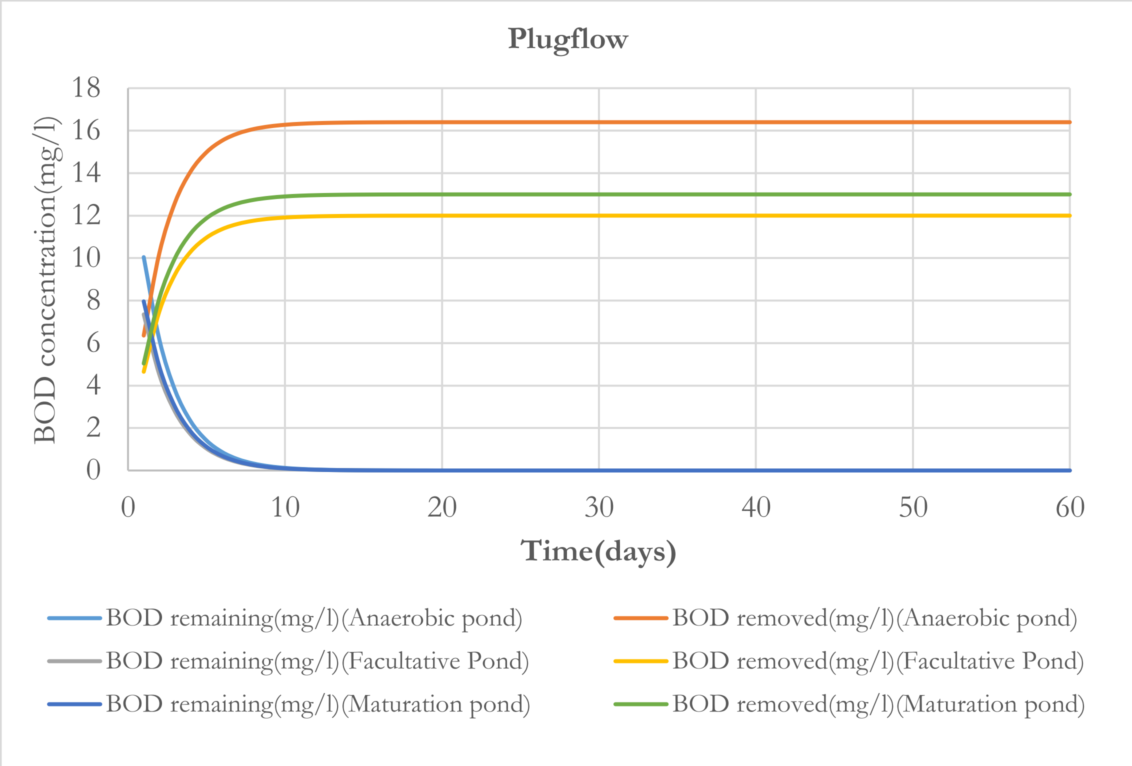


**Figure 4: BOD remaining and removal in plug flow**

The complete mix (single cell) model shows that the RMSE2 concentrations are ranged from 4.769±1.089 mg/l as indicates in Figure2, when the kinetic reactions are between 0.9-0.34 $d^{-1}$, RMSE2s are declined between 6.223703 mg/l -3.825 mg/l, and the kinetic reactions are greater than 0.34 $d^{-1}$, the RMSE2s are increasing from 3.825 mg/l to 6.462 mg/l, in this period, Figure5 depicts that the $BOD_5$ remaining and removal are fitted in the model of complete mix (single cell) with appropriated Coefficient of determination is 0.956.

Figure6 depicts the $BOD_5$ remaining and removed concentration in complete mix (single cell) hydraulic regime, in anaerobic pond, facultative pond and maturation pond:

- At day 5 the remaining concentrations are 9.11 mg/l, 6.666 mg/l and 7.2222 mg/l, in the meantime, the removed concentrations are 7.288 mg/l, 5.33 mg/l and 5.78 mg/l, respectively.
- At day 10 the remaining concentrations are 6.31 mg/l, 4.61mg/l and 5.00 mg/l, simultaneously, the removed concentrations are 10.092 mg/l, 7.38 mg/l and 8.00 mg/l, respectively.

- At day 15 the remaining concentrations are 4.82 mg/l, 3.529411765 mg/l and 3.823 mg/l, meanwhile, the removed concentration are 11.576 mg/l,8.47 mg/l and 9.18 mg/l, respectively.
- At day 30 the remaining concentrations are 2.83 mg/l, 2.068 mg/l, and 2.241 mg/l, concurrently, the removed concentrations are 13.57 mg/l, 9.93 mg/l and 1.08 mg/l, respectively.
- At day 60 the remaining concentrations are 1.55 mg/l, 1.1320 mg/l and 1.226 mg/l, during this period, the removed concentrations are 14.8528 mg/l. 1.09 mg/l and 1.18 mg/l, respectively.

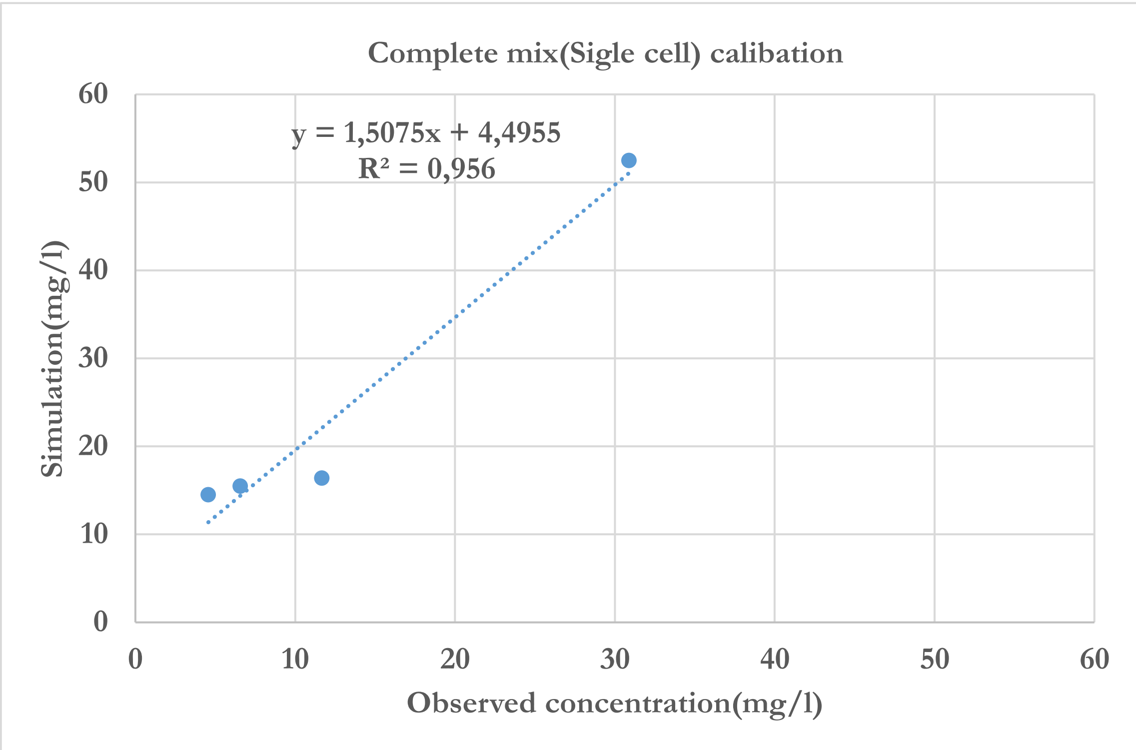


**Figure 5: Observed and simulated concentration in complete mix(Single cell)**

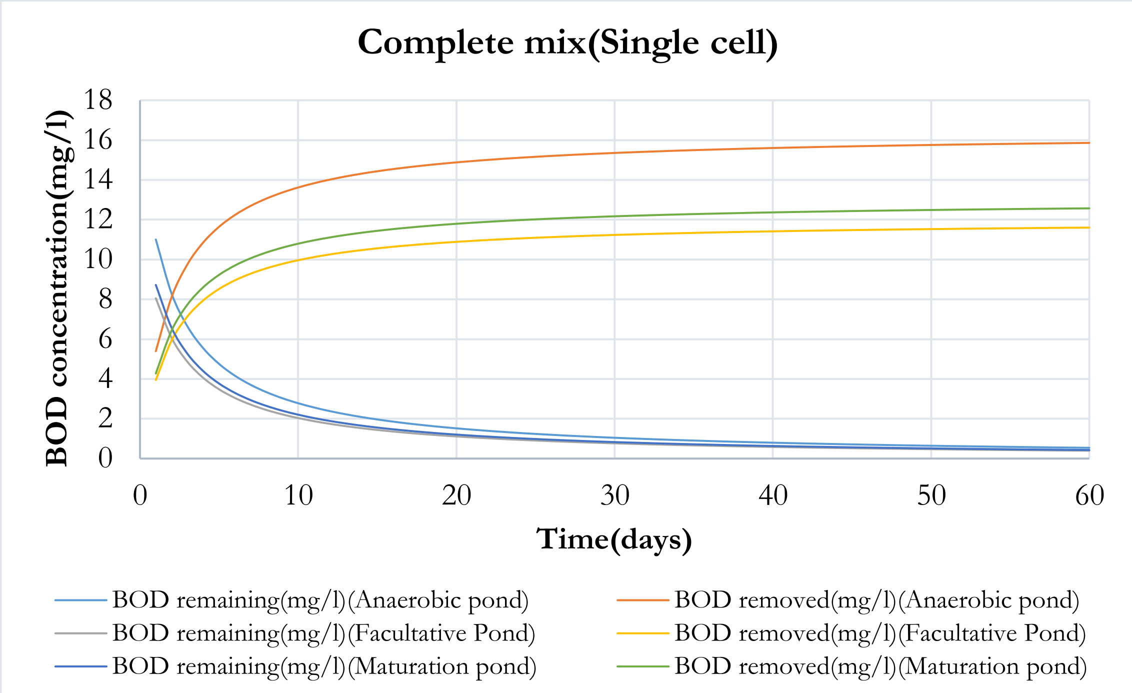


**Figure 6: BOD remaining and removal in complete mix(Single cell)**

The complete mixed (equal cells in series) model depicts that the RMSE3 concentrations are ranged from 5.849±1.677 mg/l as illustrations in Figure2, when the kinetic reactions are between 0.9-0.16 $d^{-1}$, RMSE3s are declined between 5.160349 mg/l - 3.33078 mg/l, and the kinetic reactions are greater than 0.16 $d^{-1,}$ , the RMSE3s are increasing from 3.33078 mg/l to 8.364738 mg/l, meanwhile, Figure7 depicts that the $BOD_5$ remaining and removal are fitted in the model of complete mixed (Equal cells in series) with appropriated Coefficient of determination is 0.9865.

Figure8 shows the $BOD_5$ remaining and removed concentration in complete mixed (equal cells in series) hydraulic regime, in anaerobic pond, facultative pond and maturation pond:

- At day 5 the remaining concentrations are 8.07 mg/l, 5.904 mg/l and 6.40, mg/l meanwhile, the removed concentrations are 2.31 mg/l, 6.1 mg/l and 6.6 mg/l, respectively.
- At day 10 the remaining concentrations are 4.55 mg/l, 3.3286 mg/l and 3.61 mg/l, concurrently, the removed concentrations are 11.85 mg/l, 8.67 mg/l and 9.39 mg/l, respectively.

- At day 15 the remaining concentrations are 2.81 mg/l, 2.057 mg/l and 2.23 mg/l, simultaneously, the removed concentrations are 13.59 mg/l. 9.94 mg/l and 1.08 mg/l, respectively.
- At day 30 the remaining concentrations are 0.93 mg/l, 0.682 mg/l and 0.74 mg/l, during this period, the removed concentrations are 15.47 mg/l, 1.13 mg/l and 1.23 mg/l, respectively.
- At day 60 the remaining concentrations are 0.22 mg/l, 0.1619 mg/l and 0.18, in the meantime, the removed concentrations are 16.18 mg/l. 1.18 mg/l and 1.28 mg/l, respectively.

According to the Plug flow complete mix (single cell) and the complete mixed (equal cells in series) sensitivities analysis. In conclusion, when the models are adjusted and calibrated days are iterated by 5 days' time, the $BOD_5$ remaining are decreased while $BOD_5$ removed concentrations are increasing.

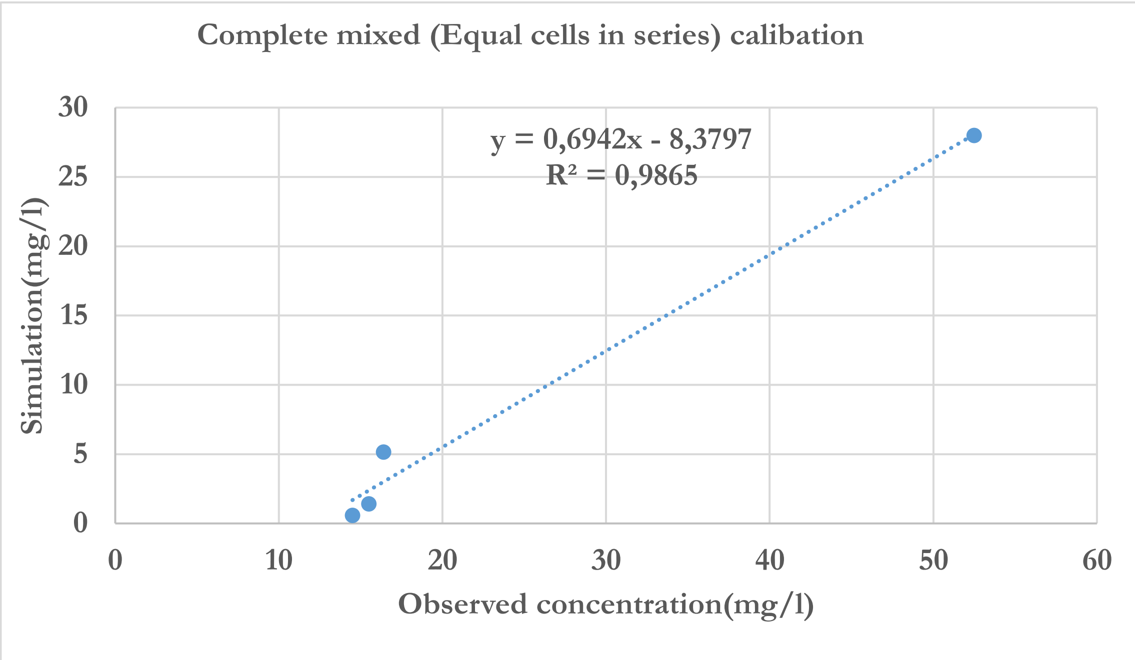


**Figure 7: Observed and simulated concentration in complete mixed (equal cells in series)**

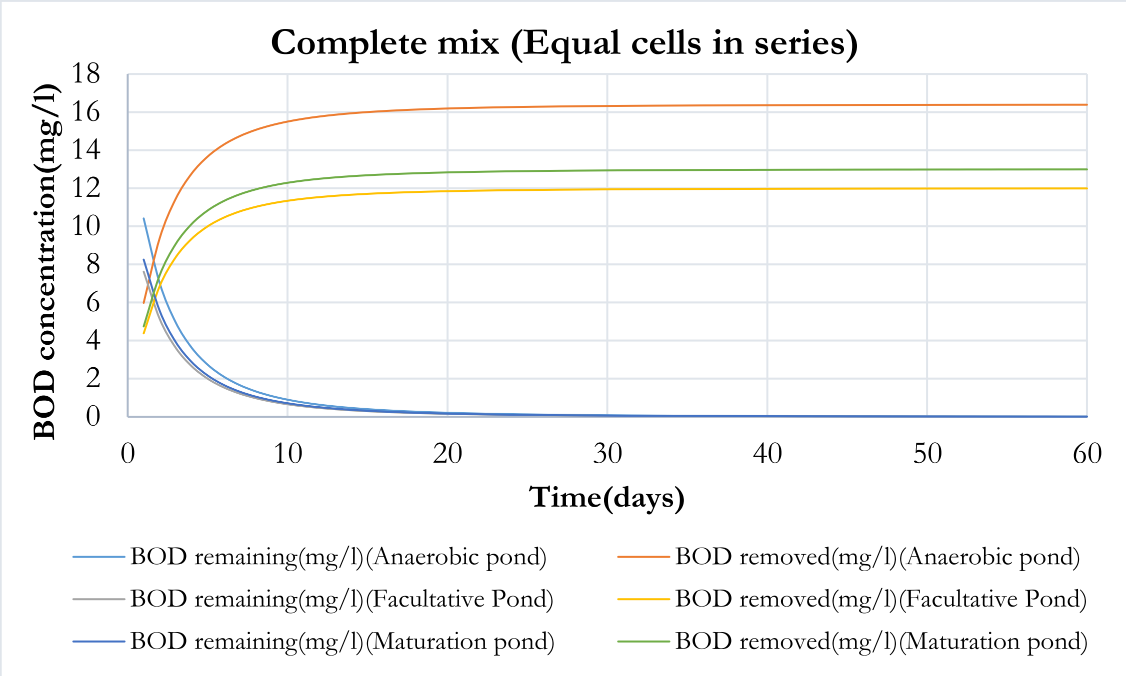


**Figure 8: BOD remaining and removal in complete mixed (equal cells in series)**

## CONCLUSION

In conclusion, the study found that the kinetic reaction value is 0.49 $d^{-1}$ as optimized value among of 3 hydraulic regimes in the model, , therefore, the coefficient of determination ($R^2$) of plug flow, complete mix (single cell) and complete mixed (equal cells in series) are 0.99, 0.95 and 0.98, respectively, they are fitted to the model between the observed and simulated concentration. The efficiency of waste stabilization pond in anaerobic pond (68.78%), facultative pond (77.14%) and maturation pond (75.24%). Hence, the concentration of $BOD_5$ in the hydraulic regime system, it is accepted to discharge to environment, it means that the waste stabilization pond is able to treat waste water and it would be good for communities in terms of environmental prevention and sustainable water and environmental health.

### Acknowledgement

Authors would like to acknowledge the Global Environment Facility (GEF) Small Grants Programme, UNDP for financial support, Department of Environmental Engineering, Department of Mechanical Engineering, Faculty of Engineering, National University of Laos that support the use of all equipment for experiments and experience

shares knowledge with team.

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