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Algal Concentration Dynamical Model Simulation in Sewon, Bantul, Yogyakarta Facultative Wastewater Treatment Pond

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Abstract. In this paper, we simulate a dynamical model of the algal concentration transport by using data collected in Sewon, Bantul, Yogyakarta facultative wastewater treatment ponds to analyse and evaluate the dynamic of the algal concentration. The governed dynamical model is consisting of the dynamical equation of the algal concentration that involves the inorganic carbon, nitrogen, phosphor, light intensity, temperature, and pH. The obtained research result was shown the evolution of the algal concentration in the pond based on the model. These results were used to observe the algal concentration time-by-time during the observation.

Keywords: **algal concentration; facultative ponds; wastewater treatment.**

1 Introduction

The amount of wastewaters in the world have been increased. Most of them were produced by industries and other human activities for example in the house. To reduce the amount of wastewater, wastewater treatment plants have been used in many countries. Wastewater treatment plants are commonly made as ponds. These ponds were used to reduce the pollutant concentration in the wastewater and they were called as stabilization ponds. In these ponds, the oxidation of the organic matter will be accomplished by bacteria with symbiosis with algae where the presence of dissolved oxygen in this process will be supplied by the algal photosynthesis and the aeration on the surface of the ponds [1]. To observe and optimize the pollutant degradation process in facultative ponds, some analysing approaches were developed. Many of them are using mathematical model to observe how the pollutant degradation process looks like in the view of chemical, biological and physical process aspects like a model of osmosis-nanofiltration on wastewater treatment plant [2], a model of carbon-nitrogen-sulfur removal process [3], a model of nitrogen removal process [4], a model of Cyhalofop-butyl removal process [5], and mathematical models observing some factors influenced the ponds like solar irradiance levels [6], aging factor [7], decay rates of some bacterias on sludge [8], dry weather [9], energy consumption effects [7, 10], and many more. Furthermore, some model application researches were also conducted to observe the performance of the wastewater treatment in some fields like domestic wastewater [11, 12] and the petrochemical industry [13].

There are many chemical, biological and physical processes occurred in a facultative pond. To analyse the whole of these processes, a huge mathematical model is needed which is difficult to build. Alternatively, a simple model can be formulated to analyse a specific process, for example, a model of the algal population on a facultative pond. Many mathematical models have been formulated to observe the algal growth in a facultative pond. It was initialized by a hyperbolic-model in [14] which was related the algal growth to the light intensity. Another basic model of algal growth is model proposed by [15] that stated as follows: the function of the nitrogen total was stated by Monod function, the phosphor intracellular was stated as Droop function and the light intensity was stated as Steele function. Another model was proposed by [16] that was formulated an algal growth model of *Chlorella Vulgaris* that was stated that the algal growth is a function of carbon dioxide and bicarbonate with carbon dioxide preference. Another one is a model proposed by [17] that the algal growth is a function of carbon dioxide, nitrogen total, and light intensity. For further analysis, some research articles found in the literature like microalgae cultivation process modelling [18], and a model on the sustainable production of algal biomass [19].

In this paper, we apply an algal mathematical model that including several factors including light intensity to analyze the algal growth and concentration in the facultative ponds in Sewon Bantul wastewater treatment plant in Indonesia. The model is in a differential equation that describes the dynamics of the algal concentration in the pond. Furthermore, computational simulation with some data taken in Sewon Bantul

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wastewater treatment plant (WWTP) is considered to observe the algal concentration time by time.

2 Material and Method

The research was conducted in Sewon Bantul facultative wastewater treatment ponds. There are four facultative ponds where each pond is illustrated in Figure 1. The wastewater entered the facultative pond through the inlet pipe. Then, the treatment is done in this pond. The algal concentration observed in this research is in the water basin where the wastewater sample was taken on the surface of the pond.

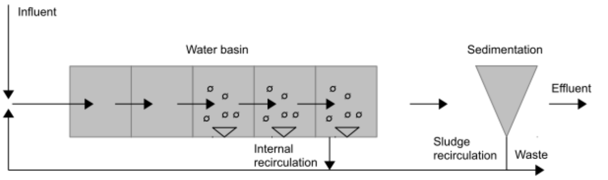

Fig. 1. Illustration of Sewon Bantul WWTP

The included factors in the used model are inorganic carbon, nitrogen, phosphor, light intensity, temperature, and PH. Let *I(z)* be the light intensity at a point with distance *z* from the light source. We follow the Lambert-Beer function $I(z) = I_0 e^{-kz}$ where I_0 is the light intensity of the light source and *k* is the attenuation coefficient of the light. We have used the algal growth model formulated in [17] to be simulated by using the collected data in Sewon Bantul WWTP. The governed equation is

$$\frac{dX_A}{dt} = \mu_{\max} f(I) \cdot \frac{S_{NH4} + S_{NO3}}{K_{NH4+NO3} + S_{NH4} + S_{NO3}} \cdot \frac{S_{CO2}}{K_{CO2} + S_{CO2}} \cdot X_A \quad (1)$$

where $f(I) = \frac{I}{I_{opt}} e^{I - \frac{I}{I_{opt}}}$ is Steele function, X_A is the algal concentration at time *t*, K_{CO2} is the half-saturation coefficient for CO_2 which is 0.2 $g(CO_2)m^{-3}$, S_{CO2} is the substrate of CO_2. The maximum growth $\mu_{\max}$ is between 0.48 d^{-1} and 0.52 d^{-1} where the half-saturation coefficient for CO_2 and NH_4+NO_3 which are K_{CO2} and $K_{NH4+NO3}$ is 0.001 $mol.m^{-3}$ for each.

We assume that the four facultative ponds are uniform, then we take the sample wastewater only in one facultative pond. We have collected the algal concentration in three groups of time i.e. afternoon, evening, and at the morning where each of the group has four sampling points A1, A2, A3, and A4 spreading in the facultative pond.

Table 1. Algal concentration at each sampling point and sampling time

Algae Concentration	Sampling point				Average
Sampling Time	A1	A2	A3	A4	
11.50 – 13.10	36	39	31	51	39
18.50-19.55	42	35	35	55	42
05.50-06.40	41	30	30	35	34

To simulate the model, we have collected the date for the algal concentration in the facultative pond. The algal concentration data sampling was conducted in Sewon Bantul WWTP in September 2017 with four sampling points for each sampling time where the data is given in Table 1. The sampling time displayed in Table 1 is the duration to take the sample since we were not taken the sample in all points at the same time.

```
%Parameters
miu_max=0.79;  SCO2=0.001;
KCO2=0.2;      SNH4=0.001;
SNO3=0.019;    KNH4NO3=0.002;
y0=36;         Iopt=2;
kcah=0.01;     z=0.00001;    I0=-3.2;
syms y(t)
eqn = diff(y,t) == miu_max*((I0*exp(-
kcah*z))/Iopt)*exp(I0*exp(-kcah*z)-(I0*exp(-
kcah*z)/Iopt))*SCO2/(KCO2+SCO2)*(SNH4+SNO3)/(KN
H4NO3+SNH4+SNO3)*y;
cond = [y(0)==y0];
ysol=dsolve(eqn,cond)
t=0:0.01:5;
solusi=36*exp(-
(5322882967022311*t)/4611686018427387904)
figure
plot(t,solusi,'-g',...
    'LineWidth',2)
xlabel('Time (hour)')
ylabel('Algal Concentration (Ind/Liter)')
```

Fig. 2. Matlab code for simulation 1

```
%Parameters
miu_max=0.79;  SCO2=0.001;
KCO2=0.2;      SNH4=0.001;
SNO3=0.019;    KNH4NO3=0.002;
y0=42;         Iopt=1;
kcah=0.01;     z=0.00001;    I0=-5;
syms y(t)
eqn = diff(y,t) == miu_max*((I0*exp(-
kcah*z))/Iopt)*exp(I0*exp(-kcah*z)-(I0*exp(-
kcah*z)/Iopt))*SCO2/(KCO2+SCO2)*(SNH4+SNO3)/(KN
H4NO3+SNH4+SNO3)*y;
cond = [y(0)==y0];
ysol=dsolve(eqn,cond)
t=0:0.01:11;
solusi=42*exp(-
(40228893598353*t)/2251799813685248)
figure
plot(t,solusi,'-g','LineWidth',2)
xlabel('Time (hour)')
ylabel('Algal Concentration (Ind/Liter)')
```

Fig. 3. Matlab code for simulation 2

```
%Parameters
miu_max=0.79;  SCO2=0.001;
KCO2=0.2;      SNH4=0.001;
SNO3=0.019;          KNH4NO3=0.002;
y0=34;               Iopt=2;
kcah=0.01;  z=0.00001;  I0=3;
syms y(t)
eqn = diff(y,t) == miu_max*((I0*exp(-
kcah*z))/Iopt)*exp(I0*exp(-kcah*z)-(I0*exp(-
kcah*z)/Iopt))*SCO2/(KCO2+SCO2)*(SNH4+SNO3)/(KN
H4NO3+SNH4+SNO3)*y;
cond = [y(0)==y0];
ysol=dsolve(eqn,cond)
t=0:0.01:5;
solusi=34*exp((3461632621584501*t)/144115188075
855872)
figure
plot(t,solusi,'-g','LineWidth',2)
xlabel('Time (hour)')
ylabel('Algal Concentration (Ind/Liter)')
```

Fig. 3. Matlab code for simulation 3

3 Results and Discussions

For simulation purposes, the algal concentration data shown in Table 1 are used as the initial value to the mathematical model. We have done three simulations. The first simulation is conducted for afternoon condition, the second simulation is conducted for the evening condition and the third simulation is conducted for morning condition at the pond. All of the simulations were computed in MATLAB 2017b with windows 10 x64 of the operating system, Dual Core 3.0 GHz of processor and 4 GB of memory by using Listing code 1 for the first simulation, Listing 2 for the second simulation, and Listing code 3 for the third simulation.

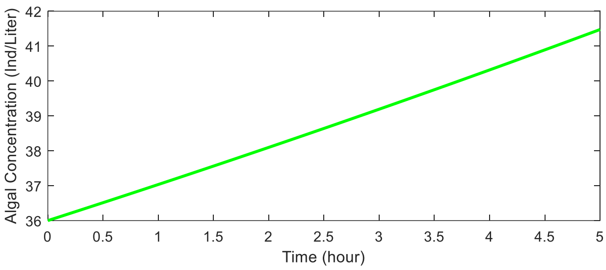

Fig. 4. Result for the first simulation

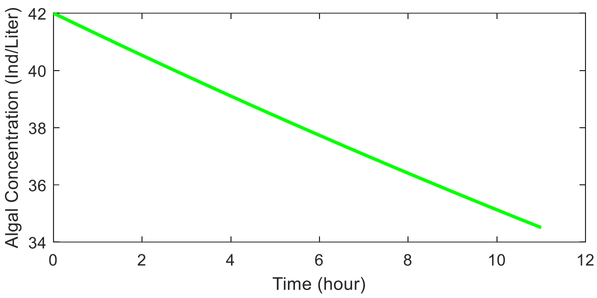

Fig. 5. Result for the second simulation

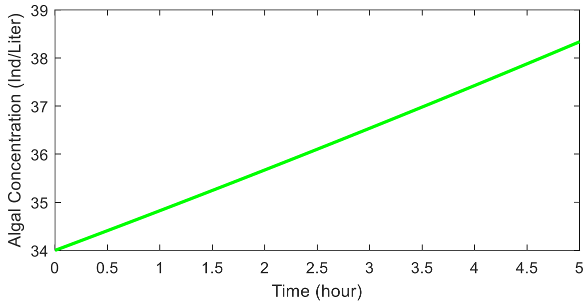

Fig. 6. Result for the third simulation

For the first simulation, at the first time of sampling, we have chosen 36 at sampling point A1 as the initial value of the model. The results are illustrated in Figure 3 to Figure 5. This model simulation is computed for hour 1 to hour 5 which represents time 13.00 to 17.00. It can be seen that in the first hour, the concentration is 36 and by following the time the concentration was increased and it was reached about point 41.5. For the third simulation, it was simulated for the time in the morning of the day which is 07.00 – 11.00 (5 hours) where the initial point is 34. In the morning the presence of the light is well and the simulation result was shown that the algae concentration was increased and reach at a point about 39.

The simulation results shown in Figure 3-5 appeared to be a linear curve which means that the algal concentration to be increased linearly illustrated in Figure 3 and Figure 5 which was caused by the presence of the light or decreased linearly caused by the absence of the light. Although the simulation resulted in a linear appearance, the real algal concentration may not linearly increase/decrease. To observe that, we need to compare the simulation result to the real data for many time samplings, e.g. every five minutes during one day and one night. But to collect this data, it will need more effort. So, we will observe that for our next works.

4 Conclusion

In this paper, the simulation and analysis of the facultative wastewater treatment ponds by using a mathematical model of the algae concentration transport in Sewon Bantul WWTP were considered. The used mathematical model has represented the algae concentration involved by the inorganic carbon, nitrogen, phosphor and light intensity. The simulation results were shown that the used mathematical model was sufficiently appropriate to analyze the algae concentration in Sewon Bantul WWTP.

In our future works, we will apply the more advanced model to analyze the performance of the Sewon Bantul WWTP. Parameter estimation will also be performed to find the best parameter that is most suitable to the model and is optimizing the performance of the WWTP.

References

1. B. Beran, F. Kargi, Ecol. Modell. **181** (2005)

2. P. Pal, M. Sardar, M. Pal, S. Chakrabortty, J. Nayak, Comput. Chem. Eng. **127** (2019)
3. X. J. Xu et al., J. Hazard. Mater. **321** (2017)
4. L. Peng et al., Bioresour. Technol. **267** (2018)
5. P. Wu et al., Bioresour. Technol. **282** (2019)
6. J.S. Arcila, G. Buitrón, Algal Res. **27** (2017)
7. L. Castellet-Viciano, V. Hernández-Chover, F. Hernández-Sancho, Sci. Total Environ. **625** (2018)
8. K.R. Schwarz et al., Water Res. **154** (2019)
9. L.M. Cook, C. Samaras, J.M. VanBriesen, J. Environ. Manage. **206** (2018)
10. Y. Yu, Z. Zou, S. Wang, J. Environ. Sci. **75** (2019)
11. S. Sunarsih, P. Purwanto, W.S. Budi, J. Urban Environ. Eng. **7** (2013)
12. Sunarsih, Widowati, Kartono, Sutrisno, E3S Web Conf.,**31** (2018)
13. É. Hansen, M.A.S. Rodrigues, M.E. Aragão, P.M. de Aquim, J. Clean. Prod. **172** (2018)
14. A. Tamiya, H., Hase, E., Shibata, K., Iwamura, Y. Morimura, *Kinetics of growth of chlorella, with special reference to its dependence on quantity of available light and temperature. Algal culture: From Laboratory to Pilot Plant* (1953)
15. Y.H. Wu, X. Li, Y. Yu, H.Y. Hu, T.Y. Zhang, F.M. Li, Bioresour. Technol. **144** (2013)
16. Decostere, B. et al., Chem. Eng. J. **222** (2013)
17. A. Yang, *Modelling and Evaluation of CO 2 Supply and Utilisation in Algal Ponds,* Univ. Surrey, Guildford, UK, (2011)
18. M. Bello, P. Ranganathan, F. Brennan, Algal Res. **24** (2017)
19. I. Ambat, W.Z. Tang, M. Sillanpää, Biomass and Bioenergy **120** (2019)