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RESEARCH PAPER

Plant growth and total Nitrogen absorption rate in leachate with water hyacinth (*Eichhornia crassipes*)

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Abstract. Phytoremediation is a simple technique of wastewater processing by utilizing the plant activity to vanish, replace and stabilize or destroy the pollutant either organic compound or inorganic. This research utilizes *Eichhornia crassipes* as the biofilter in handling the leachate produced from organic waste degradation. The purposes of this research are to find out the plant growth rate and total Nitrogen (N) absorption in leachate by the *Eichhornia crassipes*. The experiment shows that the concentration of leachate affects the absorption rate of total N and wet weight of the plant. The model was fit to the experimental data. The metabolism reaction rate constant (k_r) and absorption rate constant (k_1) at leachate concentration 5%, 10%, 15%, 20%, 25% and 30% were measured. The highest reaction rate constant and absorption rate constant were 5% of leachate concentration where k_r= 0.008042/day and k_1= 2.30811/day, whilst at the leachate concentration of 30% reaction rate constant and absorption rate constant were the lowest where it reached k_r= 0.00029/day and k_1= 0.04576/day. The absorption ability of water hyacinth to absorb the N which contained in the leachate was affected by the metabolism reaction rate of nitrogen in the plant and the reaction rate of nitrogen degradation into ammonia (NH_4) and nitric ion (NO_3) in the plant root. The leachate concentration affected the efficiency of N absorption by the water hyacinth. The efficiency of N absorption at leachate concentration of 5; 10; 15; 20; 25 and 30 were 89.81%, 68.99%, 49.51%, 36.32%, 30.28% and 21.64% respectively. Overall, this technique presents a simple technique approach and the utilization of elements contained in the leachate as the nutrition for plant.

Keywords: absorption; water hyacinth; leachate; metabolism reaction; degradation reaction

1. Introduction

Fluid leakage (leachate) which is an organic pollutant (Zurbrügg et al., 2012) produced by sanitary landfills is harmful to the environment (Fazeli et al., 2016). Leachate is the product of organic compound decomposition. Leachate usually contains dissolved organic compounds and inorganic ions in high concentration. The liquid produced from organic waste degradation is

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known to have a high concentration of Nitrogen (N), Phosphate (PO_{43-}) and Kalium (K). Leachate also contains secondary and micronutrient, such as iron (Fe) Calcium (Ca), Chlore (Cl) and has relatively neutral pH (Tchobanoglous et al., 1977).

One of the elements contained in the leachate is Nitrogen which is an essential nutrient for plant. However, the excess of nitrogen has a negative impact on human health because it has potential influence vector-borne diseases, such as malaria and cholera (Townsend et al., 2003). The high concentration of nitrogen will cause the rapid growth of algae in the water or surface water (algae bloom) (Yeesang & Cheirsilp, 2011). It leads to harm to the ecosystem's balance. The growth of algae reduces the quality of Nitrogen that causes the decease of a blue baby if the water is consumed (Li et al., 2008; Mcisaac, 2003). This case is the reason for the importance of total Nitrogen (N) concentration reducing in wastewater .

Plant as biological waste treatment is one of the effective and cheap treatments to remove pollutants from wastewater. It is also eco-friendly wastewater treatment. The plant activity utilization to remove the pollutant is known as phytoremediation. Water hyacinth (*Eichhornia crassipes*) is a kind of plants that is able to be used for bio-filter in addition to moringa seed (*Moringa oleifera*), neem (*Azadirachta indica*) and tulsi (*Ocimum teuiflorum*) because of its ability to absorb toxic substances and heavy metal in the water (Jafari, 2010; Privya & Panicker, 2019).

The research related to the water hyacinth (*Eichhornia crassipes*) as a bio-filter to reduce the pollutant concentration of organic or inorganic pollutants in wastewater has been conducted by many researchers. The study of Sayago and Torres (2017) shows that *Eichhornia crassipes* reduces BOD in wastewater because of the oxygenation and nutrients to plants. A similar result is proved by Fadhillah et al. (2018) and Rodfriguez-Espinosa et al. (2018). Meanwhile, a study of Mal et al. (2015) shows that there is a significant reduction of electrical conductivity, pH, turbidity, nitrate, phosphorus, and orthophosphate after passing *Eichhornia crassipes* bio-filter, but it does not change the concentration of nitrogen, nitrate and ammonium ion.

The ability of *Eichhornia crassipes* to absorb heavy metal has also been studied by some researchers. Mardalena et al. (2018) study shows that *Eichhornia crassipes* is the best bio-filter to absorb Manganese (Mn) in coal mining wastewater in comparison to water lettuce (*Salvina natans*) and floating fern (*Pistia stratiotes*). According to Al-Rubaie and Al-Kubaisi (2015) *Eichhornia crassipes* is a better plant than Ceratophyllum demersum for wastewater phytoremediation of Pb. Meanwhile, a study of Tabinda et al. (2018) has proven that *Eichhornia crassipes* is better than *Pistia stratiotes* in removing chromium. Zaki t al. (2015) performed a response surface methodology to find out the optimum effectiveness of the value of *Eichhornia crassipes* on the removal of heavy metal from wastewater . This study addresses to perform the mathematical model of water hyacinth ability in absorbing the total nitrogen in leachate.

2. Literature review

2.1. Leachate

Damanhuri (1993) defines the leachate as the liquid which seeps through the bulk of garbage by carrying dissolved or suspended material, especially from the decomposition of garbage. Leachate can also be defined as the liquid which comes through the solid waste and that liquid extracted the organic material contained in the garbage which then will be dissolved and suspended in the liquid. It may contain BOD, COD, N, Phosphorus, Kalsium, Magnesium, Potassium, Sodium, Chloride, Sulphate, and Fe (Damanhuri, 1993). Its characteristics depend on the waste composition and wastewater content (Mor et al., 2006).

2.2. Phytoremediation by using water hyacinth

Water treatment by implementing the phytoremediation system is the simple technique to reduce the environment pollution by maintaining the polluted water by using plant or micro-organism. This method is seen as low-cost treatment (Jiang et al., 2015) for removing organic and inorganic wastewater pollutants (Mishra & Maiti, 2016). Many researchers have proven that phytoremediation was able to improve wastewater quality (Mardalena et al., 2018).

Water hyacinth (*Eichornia crassipes*) has been introduced by researchers to be used for phytoremediation (e.g. Ochekwu & Madagwa, 2013; Rodfriguez-Espinosa et al., 2018; Sayago & Torres, 2017). Water hyacinth is known as waterweed which can grow rapidly despite at the polluted water. According to Marianto and Maryanto (2002), water hyacinth is categorized as a floating plant which needs no soil as its growing media, but it uses the water as its media. Water hyacinth grows by absorbing air and nutrient contained in the water. The water hyacinth growth especially the rapid one is mainly caused by the water which contains high nutrients, especially nitrogen, phosphate, and potassium. This plant grows at 28-30°C water temperature and 21-30°C air temperature (Jafari, 2010).

2.3. Nitrogen absorption by phytoremediation

Nitrogen is the main nutrient for plant growth, which generally very needed for vegetative parts of the plant, such as leaf, stem, and root. However, if it exists in too high concentration, it will hamper the efflorescence and insemination of the plant (Sutedjo, 2008). Nitrogen is absorbed by plant root in a form of NO_3^- (Nitrate) and NH_{4+} (ammonium) (Dwidjoseputro, 1990).

Affandi (2003) says that phytoremediation is one of the systems in which certain plant cooperate with microorganisms in one medium (soil, coral, water) to decrease the contaminant or convert the contaminant to be non-poisonous or even become economically useful compound. The process in this system occurs naturally with the series of steps done by the plant toward the contaminant located around it, those are Phytoaccumulation, Rhizofiltration, Phytostabilitation, Rhizodegradation, Phytodegradation (phytotransformation), and Phytovolatilization.

Absorption which occurs in the planting media to the plant root and the body is a process of mass transfer. The process that occurs in the plant of water hyacinth is the absorption process through the root and pollutant reaction process for metabolism in the plant body. The new compound as the result of metabolism will spread to all parts of the plant. The absorption rate of total N in every mass unit of water hyacinth explained in the following equations.

$$\frac{dC_1}{dt} = -\frac{k_r' \cdot Cl \cdot M}{V} \tag{1}$$

$$\frac{dM}{dt} = -k_1' \cdot Cl \cdot M - k_2{}' \cdot M \qquad (2)$$

Note that: $k_r' = \frac{k_r}{H}$ and $k_1' = \frac{k_1}{H}$

The values of k_r', k_1' and k_2 are obtained by minimizing of Sum Square of Errors (SSE) which is defined as:

$$SSE = \sum (Cl_{\text{data}} - Cl_{\text{model}})^2 + \sum (M_{\text{data}} - M_{\text{model}})^2 \qquad (3)$$

The equations solution and data fitting presented as a chart of the correlation between plant weight versus time between the experimental data and calculation data of the analysis result by using MATLAB.

To find out the ability of water hyacinth in absorbing total N of the leachate which is affected by the reaction rate of nitrogen(metabolism) in the plant and Nitrogen degradation reaction rate into ammonia (NH_4) and Nitrate ion (NO_3^-) in the root can be calculated by the efficiency formula as follow:

$$E = \frac{Cl_{pre} - Cl_{post}}{Cl_{pre}} \times 100\% \qquad (4)$$

3. Research Method

3.1. Material

The materials used in this research are leachate of the landfills and water hyacinth. The leachate was obtained from the landfills of Piyungan, Sitimulyo, Bantul, Yogyakarta. Water hyacinth obtained from one of the fishing pond located in Pandega Martha street, Pogung Baru, Yogyakarta.

3.2. Apparatus

The apparatus used in this research are water pond made of plastic with the capacity of 1.5 Liter, measuring pipette 10 ml, measuring glass 100 ml, sample bottle 25 ml, pH meter (walklab TL1900), digital weighting (Mettler Toledo), jerry can 20 liter, and transparent plastic to cover the plant.

3.3. Research Variables

The independent variables in this research are the concentration of Nitrogen (N), the mass of water hyacinth and the aquades addition. The Concentration variation of total N in the leachate with the determined concentration are 151.03 mg/l, 316.48 mg/l, 486.51 mg/l, 602.6 mg/l, 738.00 ppm, and 904.9 mg/l. Water hyacinth with the mass of the plant is 60-70gram per group. Aquades addition is to return the volume of leachate to the initial level due to the absorption. Meanwhile, the independent variables are the total N concentration in leachate. This variable is measured in the unit of mg/l measured from the day of zero, 1, 2, 3, 4, 5, 6, 7, 8, 10, and 12 of each handling.

3.4. Experimental Execution

The procedure for the experiment is following these steps, introduction, acclimatization, water hyacinth planting, data collection through sampling, data analysis, and evaluation. Introduction and acclimatization were conducted in this experiment to investigate the level of water hyacinth adaptation to leachate concentration. The water hyacinth was planted in the leachate at the variation of N concentration at 151.03 mg/l, 316.48 mg/l, 486.51 mg/l, 602.6 ppm, 738.00 mg/l, and 904.9 mg/l with the initial volume of 1 liter. The 10 ml samples were taken for 8 days to measure water hyacinth mass. Total nitrogen level was measured using the Kjeldahl method based on SNI 06-6989.52-2005. This method is used to determine the level of organic nitrogen in water and wastewater in a macro Kjeldahl, then the ammonia formed can be determined titrimetrically.

3.5. Analysis and data evaluation

The mass of water hyacinth was measured by the digital weighing. The result of the measurement of total N in leachate obtained from the laboratory analysis using a spectrophotometer. After that, it was analyzed by using the application software of MATLAB to obtain the constant value of mass transfer equilibrium at the total N absorption of leachate by water hyacinth, in which the parameters of H, k_r, k_1, and k_2 are evaluated.

4. Result

A simulation of the mathematical model is created in this study. The model is reviewed based on the laboratory analysis of the total N remained in leachate and water hyacinth mass. Several constant values which consist of equilibrium constant (H), metabolism reaction constant in the water hyacinth (k_1), absorption rate constant (k_1) and desorption rate constant (k_2) are obtained. The results and discussion will be provided in this section.

4.1. Total N absorption and plant growth rate in leachate with water hyacinth

Figure 1 shows the observation and simulation model of N absorption, while Figure 2 shows the growth of leachate. In both figures, the observation is depicted by star, whilst the model simulation is depicted by line. It is apparent from Figure 1 that there is N concentration reduction as time goes on. In contrast, Figure 2 shows the increase in water hyacinth mass as the time increases.

The charts from Figures 1 and 2 indicate that there is a correlation between N concentration and time as well as water hyacinth growth and time. It also indicates that the reduction of N concentration at the leachate increases water hyacinth growth. It implies that the longer time of water hyacinth in wastewater that contains leachate, the lower the N concentration in the leachate. The reason is that the Nitrogen in the leachate was absorbed by the water hyacinth. It was assumed that Nitrogen is the food of water hyacinth that influences this plant's growth.

Tabel 1 is the simulation of the model by using MATLAB. From the simulation model, it obtained the metabolism reaction constants in water hyacinth's growth (k_r), absorption rate constant (k_1) and desorption rate constant (k_1). Based on Table 1, it was proven that the rate

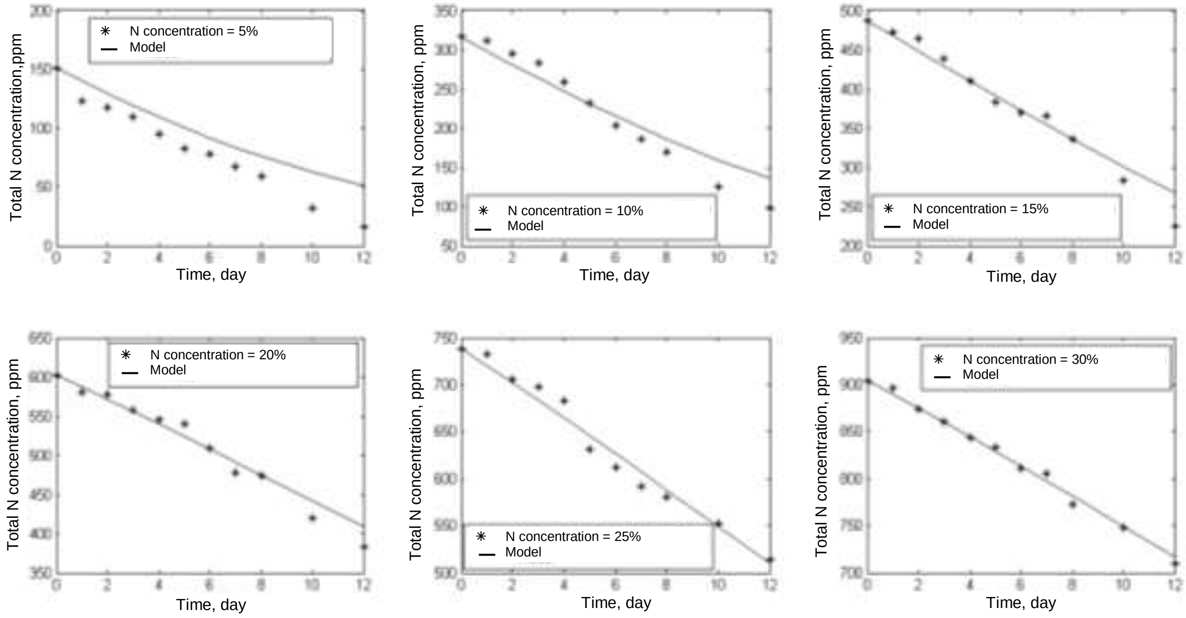

Figure 1. Chart of total N absorption rate by water hyacinth

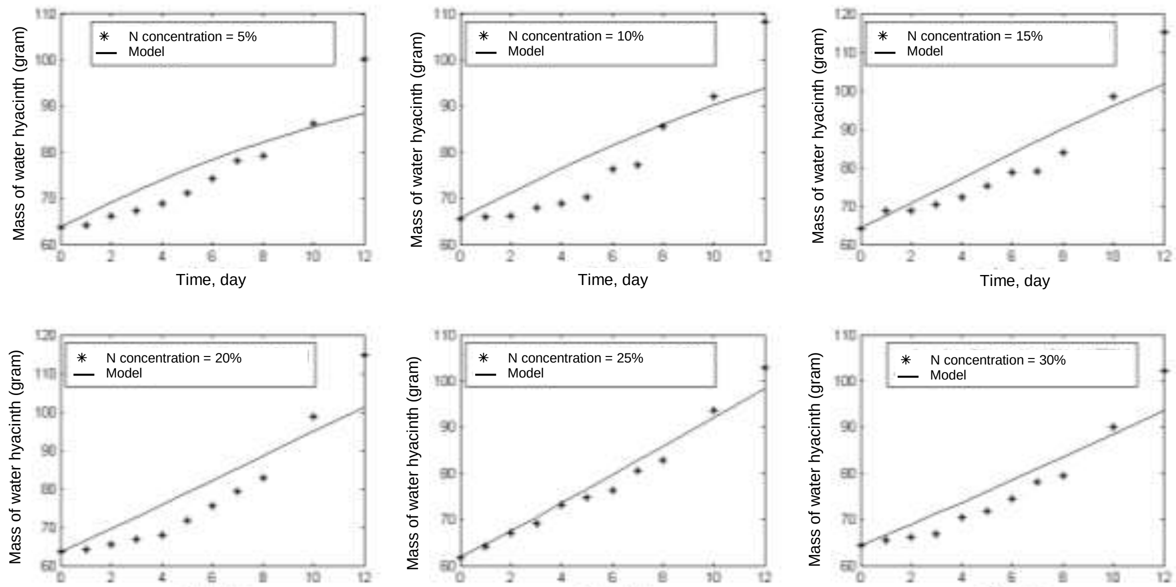

Figure 2. Chart of growing rate (mass) of water hyacinth

constant (k_1) was declining if it was compared to the reaction rate constant of metabolism in the water hyacinth (k_r) and nitrogen absorption rate constant (k_1) at the initial concentration of total N in the leachate. This case shows that at high leachate concentration, the degradation process in water hyacinth occurs very slow, so that the reaction rate constant of its metabolism is declining. The slow reaction rate of metabolism affects the absorption of Nitrogen due to the reaction rate of absorption of Nitrogen is proportional to the metabolism reaction rate of nitrogen in the body of water hyacinth. The decrease of concentration of Nitrogen occurs due to the process of Nitrogen absorption. Meanwhile, the desorption process is assumed did not occur. It is proven by the reaction rate constant obtained in a relatively small number of each N concentration in the leachate.

Table 1. Values of k_r/hour, k_1/hour, and k_2 at various concentration variation of N Total in the Leachate

No.	N Total concentration (mg/l)	k_r/hour (/day)	k_1/hour (/day)	k_2 (/day)
1	151.03	0.00804	2.3081	9.2113×10^{-13}
2	316.48	0.00306	0.5211	7.9591×10^{-11}
3	486.50	0.00136	0.2468	2.33732×10^{-14}
4	602.60	0.00069	0.1409	2.34157×10^{-13}
5	738.00	0.00058	0.0945	2.4043×10^{-14}
6	904.90	0.00029	0.0458	7.5554×10^{-14}

From the previous research, it can be known that contacted time between the leachate with the water hyacinth was longer so that the leachate concentration was reduced and the weight of the plant was increasing. In this case, it is assumed that the N contained in the leachate was absorbed by the plant, which caused the plant to grow more which was indicated by the increase of its mass.

The value of metabolism reaction rate constant in the water hyacinth (k_r) and nitrogen absorption rate constant (k_1) by the water hyacinth seems to be declining inversely with the increasing of N concentration toal in the leachate. This case shows that the higher concentration of N in the leachate will affect the degradation process rate of nitrogen by a microbe in the root of the plant to form Ammonium (NH_4) and Nitrate (NO_3) which will be absorbed by the plant. Therefore, if the process of degradation in the root of the plant is slower, the constant value of metabolism reaction rate will also decrease. In other words, the slow metabolism reaction rate affects the rate of N absorption of Total N by the plant, because the absorption reaction rate of total N is proportional to the metabolism reaction rate of nitrogen inside the plant.

4.2. The efficiency of total N absorption in leachate by water hyacinth

Table 2 shows the efficiency of Nitrogen absorption in the last column. It is apparent that the efficiency of total N absorption by water hyacinth seems different significantly at each variation of N concentration in leachate. But, the margin of the value of N total from the initial and final concentration of total N in the leachate will show insignificant value. This study proves that water hyacinth has limited ability in absorbing the total N in leachate that is about 135-240mg/L. The limited ability of one element absorption by the absorber medium is called the maximum capacity of absorption. The maximum capacity of absorption of water hyacinth is affected by several factors, especially the factor of nutrition needed by the plant to grow and generate maximally.

Tabel 2. The efficiency of total N absorption in leachate by water hyacinth

No.	Initial Concentration of N (mg/l)	Final Concentration of N (mg/l)	Efficiency (%)
1.	151.03	15.39	89.81
2.	316.48	98.14	68.99
3.	486.51	245.62	49.51
4.	602.60	383.72	36.32
5.	738.00	514.50	30.28
6.	904.90	709.05	21.64

In overall from this study, it is found that the ability of water hyacinth (*Eichhornia crassipes*) in absorbing total N in leachate and the fitting of simple mathematic model of the growth rate of water hyacinth (*Eichornia crassipes*) is related to the total N absorption in leachate by the *Eichhornia crassipes* at the various determined concentration. It is known that there are simultaneous processes in water hyacinth toward total N contained in leachate as growing medium. Those processes consist of Phytoacumulation (*phytoextraction*), Rhizofiltration (*rhizome: root*), Phytostabilization, Rhyzodegradation, Phytodegradation (*phytotransformation*), Phytovolatization.

5. Conclusion

The concentration of total N reducing in leachate due to the absorption by the plant of water hyacinth can be approached by the proportional model toward total N concentration and plant weight The higher concentration of total N in leachate will affect the efficiency of total N absorption by the water hyacinth. The values of efficiency of total N at each concentration of total N in leachate are 151.03 mg/l, 316.48 mg/l, 486.51 mg/l, 602.6 mg/l, 738.00 mg/l, and 904.9 mg/l as 89.81%; 68.99%; 49.51%; 36.32%; 30.28% and 21.64%. The higher the concentration of total N in leachate, the more the constant value of absorption rate and nitrogen metabolism rate constant in water hyacinth will decrease. In the absorption process of total N in leachate by water hyacinth is assumed that there is no desorption process because the desorption rate constant value obtained from the calculation is relatively small.

Based on the calculation by using a simple mathematic model, it was obtained that the reaction rate constant of metabolism (k_r) and absorption rate constant (k_1) at the initial concentration of total N in leachate are 151.03 mg/l as 0.008042/day and 2.30811/day; at the total N concentration of 316.48 mg/l as 0.00306/day and 0.52112/day; at the total N concentration of 486.51 mg/l as 0.00136/day and 0.2468/day; at the total N concentration of 602.6 mg/l as 0.00069/day and 0.14099/day; at the total N concentration of 738.00 mg/l as 0.00058/day and 0.09449/day at the total N concentration of total 904.9 mg/l as 0.00029/ day and 0.04576/day.

It is needed further research about mathematic model development at the growth rate and total N absorption in leachate by water hyacinth by considering several intrinsic and extrinsic factors, such as degradation by the microorganism, evapotranspiration by the plant, and other factors. For the next research, it is needed the analysis of other plant utilization as the alternative to absorb total N in leachate. The result of this research is hopefully can be the consideration as an alternative way to maintain leachate in a simple way and the utilization of elements contained in the leachate as the nutrition for the plant.

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