Survival and Performance of *Hydrilla verticillata* (L.f.) Royle and *Eichhornia crassipes* (Mart.) Solms as Phytoremediator on Leachate of Jatibarang Landfill in Semarang, Central Java

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Abstract. Leachate is liquid waste released from accumulated landfill which contains various dissolved compound, particularly organic matter. Leachate rinses the dissolved materials, as well as organic materials from biological decomposition process. Decomposition process releases decomposition result quickly using available oxygen and creates anoxic environment. Leachate can cause water pollution, both of ground and surface water that needs to be handled properly. The aim of this study to evaluate the survival and performance of *H. verticillata* and *E. crassipes* as phytoremediator on leachate of Jatibarang landfill in Semarang. This research used leachate which is combined with fresh water. There were three repetition of it is treatment. The treatment are 100% leachate, 75% leachate dissolved with 25% fresh water, 50% leachate dissolved with 50% fresh water and 25% leachate dissolved with 75% fresh water. Phytoremediator plant in fresh water without leachate served as control. Results of the study showed that the presence of *E. crassipes* was effective in increasing pH and dissolved oxygen in leachate. Compared to *H. verticillata*, *E. crassipes* shows better survival growth rates and performance. To reach an optimum remediation result the leachate should be dissolved in 25% leachate and 75% of fresh water.

1. Introduction

The landfill of Jatibarang started operating in March 1992. It is located in the upstream part of Kreo River which flows into Kaligarang River. This was the cause of serious problems such as damage to organism that live around the landfill which could decrease the level of health, nutrition, social economy of society and creates anoxic environment. All of these problem will also flow to lower Kreo river which is known to be used as a source of drinking water managed by the local government (Dinas Kebersihan dan Pertamanan Kota Semarang, 2017; Dinas Lingkungan Hidup Kota Semarang, 2017; Oktiawan & Priyambada, 2008).

Environment has the ability to degrading pollutant compounds that enter to the ground through biology and chemistry process. However, it often that pollution load in the environment is bigger than degrade process rate that pollutant naturally. The consequence, pollutant will accumulates and
it is needed human handle with existing technology to overcome that pollution. Handing polluted environment conditions can handle in method of physical, chemistry, and biology (Nugroho, 2006).

Remediation in physical and chemistry belong to short-term and incomplete. For completing the remediation is needed media removal in biology (bioremediation). In physic, recovery of polluted environment requires very high costs on transportation and procurement of energy. In addition, prevention in physic generally is used on the first prevention. The use of chemical compound as neutralizer is also requires very high costs. Furthermore, this method requires advanced technology and equipment to retract chemical compound from the environment to do not cause other negative impacts. Reviewed by costs and environmental sustainability aspect, bioremediation is more cheap and natural than in physic and chemistry on environment recovery (Christensen et al, 2001)

To handle this increasing level of environmental pollution, it is necessary to find solution using phytoremediation method. Leachate treatment by phytoremediation requires compatible species and it is specific capability to improve environmental performance. Two aquatic plant species is chosen to be studied in this case are *H. verticillata* and *E. crassipes*. It has been studied that these two aquatic plants have capability in accumulating heavy metal and potentially increase water quality (Cunningham & Ow, 1996).

The results of research conducted by Marthana et al. (2014) showed that *H. verticillata* was able to effectively reduce the levels of lead metal (Pb) contained in sediments with a biaccumulation factor value of 97.90%, and Mutmainah et al. (2015) showed that *H. verticillata* has the ability to last longer in remediating lead. Phytoremediation studies using *E. crassipes* were carried out where the results showed that *E. crassipes* was able to reduce iron (Fe), lead (Pb) and manganese (Mn) levels in leachate with a contact time of 6 days. (Suryanti et al., 2013). Wijayanti’s research (2013) showed that *E. crassipes* was able to survive at a maximum total N concentration of leachate around 988.35 mg/L. The results of research conducted by Sari, et al. (2016) showed that jasmine water, genjer and *E. crassipes* had better adaptability in leachate.

2. Purpose
The aim of this study was to analyse the survival growth rate and phytoremediator performance, and to determine the effective concentration of remediation using aquatic plants, *H. verticillata* and *E. crassipes* on leachate of Jatibarang landfill in Semarang.

3. Methods
This study was done in March-December 2018. Leachate sampling took in Landfill of Jatibarang Semarang. Tested and Analyzed was done in Laboratory of Ecology and Biosystematics Biology Department Faculty of Science and Math Diponegoro University, Semarang.

Leachate samples was taken from Jatibarang Landfill, Semarang, where are *H. verticillata* and *E. crassipes* is taken from Rawapening Lake. The location map is shown in Figure 1 and Figure 2 and is marked with a red square.
To optimize the effectiveness of aquatic plants as phytoremediator, three treatments were introduced, those are:

- **T0**: Leachate without phytoremediator, served as controls.
- **T1**: Leachate with phytoremediator *H. verticillata*
- **T2**: Leachate with phytoremediator *E. crassipes*

We evaluate survival and performance of phytoremediator plants, while water quality was monitored including pH and dissolved oxygen changes. For test the survival and performance of bioremediator plant after giving the treatment. This study using leachate waste which combined by fresh water. Mixture concentrate of leachate and fresh water on this treatment was different those were the treatment using 75% of leachate and 25% of fresh water, the treatment using 50% of leachate and 50% of fresh water and the treatment using 25% of leachate and 75% of fresh water. The treatment used *H. verticillata* and *E. crassipes* which were repeated by 3 times and there was no
repetition for control so there would be 19 trial reactor units. Seven treatments were introduced, those are:
T0 : Plant in fresh water, served as controls
T1 : The treatment using 75% of leachate and 25% of fresh water with *H. Verticillata*
T2 : The treatment using 50% of leachate and 50% of fresh water with *H. Verticillata*
T3 : The treatment using 25% of leachate and 75% of fresh water with *H. Verticillata*
T4 : The treatment using 75% of leachate and 25% of fresh water with *E. crassipes*
T5 : The treatment using 50% of leachate and 50% of fresh water with *E. crassipes*
T6 : The treatment using 25% of leachate and 75% of fresh water with *E. crassipes*

Resulted data was collected and analyzed using SPSS 17.0 for Windows computer program and viewed the data distribution curve with the Shapiro-Wilk test to determine the normality of the data and the homogeneity test using Levene test. Then using One way ANOVA to find meaningful differences among all treatment groups. Furthermore, to find out the differences between treatment groups Duncan's advanced test was used. The degree of significance used is $\alpha = 0.05$.

4. Result and Discussion

4.1 Result

4.1.1 Survival of Phytoremediator

Survival of *H. verticillata* and *E. crassipes* in leachate after 3 and 6 days is showed in Fig. 3 and Fig. 4.

As it is showed in Fig. 3 (A) that *H. verticillata* growth in control media (fresh water) indicated in normal condition. There was significant different on survival of *H. verticillata* growth in leachate. It showed change in color and survival. The green color was becoming fade away and turned into blackish green. The rod was weak and wilted, even though the leaf still looked strong and firm. These conditions showed on all treatment.

After 6 days of observation, *H. verticillata* was getting weaker and indicated by detachment of leaf from it stem.

![Figure 3. Survival of *H. verticillata* after 3 days growing in leachate](image)
A: Survival of H. verticillata growth in fresh water
B: Survival of H. verticillata in 75% leachate and 25% fresh water
C: Survival of H. verticillata in 50% leachate and 50% fresh water
D: Survival of H. verticillata in 25% leachate and 75% fresh water

Survival of E. crassipes growth in fresh water (controls) showed in normal growth, healthy with shiny green leaves, the leaves did not shrink, the rod look sturdy, hard and green color (Fig. 4A). In media of leachate mixed with 25% of fresh water indicated change performance of E. crassipes, where their leave becoming changed in colour, form and size (Fig. 4B). This change was also typically performed by E. crassipes planted in 50% of leachate mixed with 50% of fresh water (Fig. 4C). This typical changes also performed by E. crassipes planted in 25% leachate mixed with 75% fresh water, but the stem still strong and hard if it was touch (Fig. 4D). In media of 50% leachate and 50% fresh water, after 6 days, only five leaf was still attached to its stem, while other leave (approximately 10 leave) were detached already (Fig. 4F). If 25% of leachate dissolved by 75% of fresh water, the E. crassipes performed by ten leave blade left attached in its stem (Fig. 4G).

Figure 4. Survival of E. crassipes after planted in different concentration of leachate

Note:
A: Survival of E. crassipes without leachate
B: Survival of E. crassipes in 75% of leachate and 25% of fresh water at the third day
C: Survival of E. crassipes in 50% of leachate and 50% of fresh water at the third day
D: Survival of E. crassipes in 25% of leachate and 75% of fresh water at the third day
E: Survival of E. crassipes in 75% of leachate and 25% of fresh water at the sixth day
F: Survival of *E. crassipes* in 50% of leachate and 50% of fresh water at the sixth day 

G: Survival of *E. crassipes* in 25% of leachate and 75% of fresh water at the sixth day

### 4.1.2 Phytoremediator Growth Rate

Observation result of survival on bioremediator plant that treated by different leachate concentrate during waiting time 6 days was served in initial weight average form, final weight, and dry weight (Table 1).

**Table 1.** Phytoremediator Growth Rate in different concentration of leachate after treated by phytoremediation for 6 days.

| Treatment | ∑ Initial Fresh Weight (g) | ∑ Final Fresh Weight (g) | ∑ Final Dry Weight(g) |
|-----------|---------------------------|--------------------------|-----------------------|
| **T0 HV** (H. verticillata in fresh water, served as controls) | 80,5 | 80,8 | 72,3 |
| **T0 EC** (E. crassipes in fresh water, served as controls) | 297 | 303 | 265 |
| **T1** (75% leachate, 25% fresh water with H. Verticillata) | 80,3 | 0 | 0 |
| **T2** (50% leachate, 50% fresh water with H. Verticillata) | 80,6 | 0 | 0 |
| **T3** (25% leachate, 75% fresh water with H. Verticillata) | 80,1 | 0 | 0 |
| **T4** (75% leachate, 25% fresh water with E. crassipes) | 293 | 324 | 171 |
| **T5** (50% leachate, 50% fresh water with E. crassipes) | 301 | 331 | 194 |
| **T6** (25% leachate, 75% fresh water with E. crassipes) | 290 | 320 | 162 |

### 4.1.3 Chemical Analysis and Physical of Jatibarang Landfill Leachate

Sample of leachate was taken from first pool (inlet) of landfill and mixed thoroughly in 1:1 ratio. The data of leachate quality indicator was performed in Table 2 as follows:

**Table 2.** The chemical and physical conditional leachate before treated by phytoremediator

| Parameter     | Inlet (T0)     |
|---------------|----------------|
| pH            | 6,12           |
| DO            | 2,45 ppm       |
| Pb            | 0,0087 ppm     |
| Sulfate       | 46,674 ppm     |
| Ammonia       | 9,822 ppm      |
| Turbidity     | 111 NTU        |

### 4.1.4 Phytoremediator Performance at 100% Leachate

Resulted data of pH and DO after treated by these two aquatic plant species on leachate was performed in the following Table 3.
The results of data analysis of the calculation of pH and DO leachate after being treated with the Shapiro-Wilk test, obtained a significance value on the data pH and DO on first day, and sixth day showed value greater than α (0.05). This shows that the data is normally distributed. The Levene’s test shows that the value of p> 0.05 on all parameter data at all time observations except for the DO values at the sixth day observations, which is 0.000 and 0.013 which indicate that the data is not homogeneous. The pH value data on all observation days were 0.548 and 0.568. DO value data on first day observation days is 0.116. This shows that there is no difference in variance between groups compared (homogeneous data variance). On the One-Way ANOVA test, it was obtained a significance value of p <0.05 on pH and DO data on the sixth day indicating that there were significant differences in mean values. Whereas the pH and DO data on the first day observation time obtained a significance value of p> 0.05 indicating that there were no significant differences. Data on pH and DO parameters were then analyzed further by the Duncan test to find out the differences between treatments. The data in Table 3 shows that there were no significant differences between T0, T1 and T2 on the first day observation for all parameter value.

The pH value at the sixth day observation showed a significant difference between T0 with T1 and T0 with T2. However, there is no significant difference between T1 and T2. On the first day observations there was no significant difference between T0 with T1, T0 with T2 and T1 with T2.

Table 1 also shows that there are significant differences in DO values on the sixth day observations, namely T0 with T1, T0 with T2 and T1 with T2. The unreal difference is shown on the first day.

4.2 Discussion

Quantitative data on Table 3. Shows that H. verticillata and E. crassipes could improve Dissolved Oxygen (DO) on leachate.

Analysis result (Table 3) on Dissolved Oxygen (DO) of leachate on the sixth day observation showed that DO value on T1 and T2 was higher than the average of 3.92 ppm and 4.57 ppm compared to controls (T0). DO value in control was lower than in treatment. The presence of aquatic plants as phytoremediator has higher because of photosynthesis process which is conducted by these plants. In controls, the lower oxygen concentration was due to the absence of aquatic plants. Aquatic plants like H. verticillata and E. crassipes was effective for increasing oxygen level in the water through photosynthesis. H. verticillata belongs to aquatic plant that the part of the body completely immersed in the water. It meant that the oxygen which used in respiration process only came from the water. It caused the oxygen concentrate dissolved in lower water than E. crassipes which part of the body was not completely immersed in the water. Carbon dioxide in photosynthesis process was absorbed and the
oxygen was released in the water. In other hand, oxygen which stand on the air can also enter in the water through diffusion process that slowly penetrate the water surface. However, oxygen concentrate that dissolved in the water depended on water saturation level itself (Gunes et al., 2014; Puspitanigrum et al., 2012). Photosynthesis process has main benefit in aquaculture, those are provided organic ingredients source for the plant itself and oxygen source which is used by all of organism in aquatic ecosystem. Oxygen source dissolved could come from diffusion that available in atmosphere and photosynthesis activity by aquatic plant (Siregar et al., 2017).

Table 2 showed high ammoniac value of leachate in inlet water was 9,822 ppm, which on this study used as negative control (T0). Ammonia value has relation with pH. The higher the pH, its ammonia contents in undissociated form is also higher (Ali, 2011). Leachate on the inlet showed a high pH average (6.12). Ammonia value has relation with DO concentration in the water. If oxygen concentration is low, usually ammonia is high, and become poisonous. In this study no further analysis was carried out on the sixth day because plant mortality was faster than expected, so only observations were made on pH and DO values then the test was continued by modifying leachate concentration.

DO level the inlet was 2.45 ppm. DO level between 5-7 ppm showed that that water in a good condition, while lower than 4 ppm showed that water excess organic matter, it meant that water was contaminated. Ammonia in the water surface came from urine, feces, and decomposition of organic substances through microbiology. High ammonia on the leachate in Landfill of Jatibarang came from urine and cow feces which in around Landfill of Jatibarang (Zaman et al., 2012).

Table 1 showed that survival and performance of H. verticillata on every treatment could stand and showed good performance until observation time on day-3 in all treatment of T1 and T2 (also shown in Fig. 3). Hence, the stem was stronger and hard, the leaves was not broken. Observation on day-6 H. verticillata was decaying, and it was indicated by broken stem and leaves detached from the stem. Based on this, table 1 shows the value of 0 for the final weight and dry weight of H. verticillata because it cannot be weighed. E. crassipes showed a better survival. It could stand on leachate until day-6, with wrinkled leaf, and color changed from green to be blackish green. Its stem was withered and fragile. The best E. crassipes survival was performed by 25% leachate dissolved in 75% fresh water (Fig. 4).

The low level of survival of H. verticillata and E. crassipes due to the high content of ammonia can reduce the level of survival of aquatic plants. This is because the high ammonia content causes oxygen to dissolve in water in critical conditions or damage the chemical content of water. Damage to the chemical water content will affect the function of water and inhibit the photosynthetic rate of plants which results in death (Ali, 2011).

A high turbidity level on leachate, in inlet caused photosynthesis rate was low. The high turbidity caused the decrease of light intensity that reduce energy source for photosynthesis, therefore it lower light absorption by chlorophyll. It caused the leaves of H. verticillata and E. crassipes were weaker (Mahmood et al., 2005).

5. Conclusion
Survival growth rate of E. crassipes was higher compared to H. verticillata. The highest survival rate of E. crassipes resulted from 75% leachate dissolved with 25% fresh water, 50% leachate dissolved with 50% fresh water and 25% leachate dissolved with 75% fresh water. Growth rate of E. crassipes was 30% / 6 days. Both E. crassipes and H. verticillata increase pH and Dissolved Oxygen. In conclusion, the best candidate phytoremediator for leachate is E. crassipes at 25% concentration of leachate. Further research is needed on other types of plants that are more effective in leachate remediation.

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