The efficiency of the phytoremediation process combination of horsetail plants (*Equisetum hyemale*) and natural filtration media to reduce the concentration of iron (Fe) in the leachate of Cilowong's Landfill Area of Banten Province

Fitri Dwirani[1]*, Ade Ariesmayana[1], and Irvan Nurhakim[1]

Environmental Engineering, Universitas Banten Jaya, Indonesia

*dwiranifitri02@gmail.com

Abstract. This research aims to determine the results of leachate sample testing and the efficiency of decreased Iron (Fe) concentration in the phytoremediation process using horsetail plants (*Equietum hyemale*) and the filtering process with zeolite, activated charcoal, and palm fibre. After testing a number of samples, there was a content of heavy metal Fe with a concentration of 7.20 mg/L. Wastewater quality standard for activities at the landfill area based on Regulation of the Minister of Environment No. 5 of 2014 concerning the quality standard of wastewater for businesses and/or activities that do not yet have a stipulated wastewater quality standard is about 5 mg/L. Based on previous research, the selection of types of horsetail plant used for phytoaccumulators is based on requirements as a plant that has high absorption and is resistant to various external influences. Based on data from the measurement of leachate samples that have been carried out experiments in leachate pond with phytoremediation processes and filtration media, it is obtained an efficiency decrease in the concentration of iron (Fe) by 54% of the total concentration of iron (Fe) leachate before the phytoremediation process. Utilization of horsetail plant in overcoming environmental pollution is expected to be developed into an environmentally, friendly and inexpensive alternative so that it can be applied optimally to the management of leachate in landfills.

1. Introduction

Leachate treatment technology at the landfill area still uses the pool system technology, which is using a storage pond, anaerobic pond, aerobic pond and stabilization pond. The concentration of several types of heavy metals contained in the leachate of landfills is very toxic and dangerous for humans and the surrounding environment.

Based on the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number: P.59/Menlhk/Setjen/Kum.1/7/2016 concerning leachate quality standards for businesses and/or activities for landfill area, it explains that the landfill area produces potential leachate polluting the environment so that there is a need for leachate treatment before being discharged to environmental bodies.

Based on the results of preliminary checking of leachate in the Cilowong's landfill area with metal parameters of Fe, Cr, Cd and Pb that the Fe content has the highest levels and exceeds the wastewater

quality standard of 7.20189 mg/L from the wastewater quality standard of 5 Mg/L. So there needs to be an effort to be able to reduce levels of Fe metals.

Industrial growth in the Serang Regency area is estimated to affect the Fe heavy metal content in the waste generation located in Cilowong's landfill area. It is considering that access to the landfill area is currently still being passed/crossed by the agency of Serang City and Serang District. Some factories such as pharmaceuticals and medicines as well as chemical processing plants are likely to influence the characteristics of solid waste generation with very high Fe content so that there is also an increase in Fe concentration in leachate. According to Ronquillo (2009) in Dhimas Firmansyah et al (2013), dissolved iron can be in the form of suspended compounds, as colloidal grains such as Fe (OH) 3, FeO, Fe2O3 and others. If the concentration of dissolved iron in water exceeds the limit, it will cause various problems, namely technical disorders in the form of corrosive deposits, physical disturbances in the form of color, odor and bad taste and health problems that can cause nausea, damage the intestinal wall and irritation to the eyes and skin.

To be able to reduce levels of Fe metals contained in leachate, it is necessary to have a treatment that can reduce it. In this study using phytoremediation by utilizing varied horsetail plants in each pond, 12, 18 and 24. Ponds containing mud were then planted with a horsetail plant where leachate water testing with variations in the number of plants was carried out on the seventh to fourteenth day. Leachate water testing was conducted at the Serang District Health Service of the Integrated Health Laboratory Service Unit using ASS (Atomic Absorption Spectrophotometer) Shimazu AA 7000. The use of horsetail plants is expected to reduce the levels of Fe metals contained in leachate. The leachate which has been phytoremediated is then filtered, where the filtration process uses a tub containing zeolite media, activated charcoal, and modified fibers. The use of phytoremediation and filtration methods are to be able to compare the efficiency of the methods that most have an effect on decreasing the Fe metal content of leachate itself.

The problems come up with this scientific paper are: 1) How are the test results and differences in Fe leachate concentration before and after treatment with the phytoremediation process of horsetail plants (Equisetum hyemale) and the filtration media?; 2) How is the efficiency of leachate water treatment to decrease Iron (Fe) concentration after receiving treatment in each pond, both phytoremediation of horsetail plants and the filtration media?

The objectives of this scientific paper are to determine the ability and efficiency of the horsetail plant as a phyto-accumulator to reduce the concentration of leachate iron (Fe); and **t**o determine the effectiveness of the filtering reactor pond through the composition of zeolite, activated charcoal, and fibers on the efficiency of reducing the concentration of leachate iron (Fe) after passing through the phytoremediation process; and to find out the physical changes that might occur in leachate after receiving treatment in the pond.

2. Method

This research is an experimental study with a laboratory scale to see the efficiency of decreased concentration of iron (Fe) leachate using experiments in a leachate water pond through the phytoremediation process of horsetail plants (Equisetum Hyemale) and the use of filter media. The data obtained will be processed descriptively quantitative.

The subjects in this study were leachate originating from Cilowong's landfill area in the Serang City of Banten Province which would be treated with a Constructed Wetlands reactor to reduce the content of Fe specific heavy metals in leachate with phytoremediation of horsetail plants and water filter media in the form of zeolites, charcoal, and palm fibers.

Figure 1. Research Location Map

The research is in the form of leachate water treatment through phytoremediation using prototype ponds for leachate of Wetland Construction system (artificial wetlands) using mud and leachate for phytoremediation process of horsetail plant with variations in the amount of the plant as many as 12, 18 and 24 planted on each pond. Leachate measurements were carried out on the 7th day to the 14th day by taking 2 times a day, at 10 am and 10 pm.

In the filtration pond that using zeolite, activated charcoal, and fibers, leachate which has been processed in the phytoremediation process will be back into the filtration pond. For each test carried out at the Regional Technical Implementation Unit of the Regional Health Laboratory of the Serang District Health Office with the AAS-7000 series atomic absorption spectrophotometer, it is prior to input into the Spectrophotometer as there is a need for sample preparation.

3. Result and Discussion

3.1. General conditions of the sample

Initial extraction and testing of Fe concentrations in leachate and mud samples were conducted separately. To be able to compare the leachate after and before the treatment. In addition, differences in air temperature, soil type and topography of the area between the location of Cilowong's landfill area and the research site will affect the changes that occur in leachate water.

The mud that is put into the reservoir is not sterilized so that the metal content of iron (Fe) in the mud is very high. This is based on environmental and regional conditions as well as the characteristics and types of soil that is clay. The result of the Fe Concentration of mud is 14.128 mg/L.

3.2. Concentration of Iron (Fe) leachate before treatment

Initial sample testing was carried out before the process to determine the condition and characteristics of leachate before the phytoremediation process was carried out in the reactor pond. Sampling was done by mixing leachate water and mud in 1000 ml of sample bottles. The type of sample taken for initial testing is the same as the type of sample to be used for the phytoremediation process in a processing rectifier. Following are the preliminary test results of Fe concentration of leachate before treatment which is presented in the table 1 below.

Table 1. Test results of Fe concentration of leachate before treatment

No	Test Parameter	Unit	Existing test results of leachate landfill pond	Test results of mixing leachate and mud in reactor pond	Test Method	Remarks
1	Iron (Fe)	mg/L	7,20189	13,5867	SNI 6989 4 2009 (AAS)	-

Source: Test Results of the Regional Technical Implementation Unit of the Regional Health Laboratory, Serang District Health Office, 2019)

Based on the test results in table 1, the amount of Fe concentration in the test results before treatment reached 13.5867 mg/L is higher than the amount of Fe concentration in the preliminary test results at seven sampling points of Cilowong's landfill area which only reached an average of 7,20189 mg/L. This is caused by the condition of the mud that already contains Fe levels so that it will affect the condition of the leachate water when it is in a pond containing mud.

3.3. The concentration of iron (Fe) leachate in phytoremediation pond

The results of testing the concentration of iron (Fe) in the three leachate ponds that have been mixed with mud/wet soil media with the same variable and in different amounts and stay time of 7 days with 2 takeouts per day, more details are summarized in Table 2 below.

Table 2. The average amount of iron (Fe) concentration of leachate in a phytoremediation pond per day

Time of Collection	Average Iron (Fe)/day concentration (Mg /L)		
	Pond 1	Pond 2	Pond 3
H_1	12,2528	11,8855	11,1812
H_2	12,4812	11,8380	11,6552
H_3	12,5039	11,9436	11,2704
H_4	12,6798	12,0266	11,2724
H_5	12,8231	12,0332	11,5660
H_6	12,9093	12,7666	11,5895
H_7	12,9613	12,8324	11,1045

Based on table 2, the concentration of iron (Fe) in the first pond tended to not decrease, even on the 7^{th} sampling there was an increase in the Fe concentration reaching 12.9613 mg/L. While in the second pond, the results showed an increase on the 4^{th} day to the 7^{th} day. The test results with the lowest Fe concentration values were the third pond which reached an average of 11.10 mg/L.

Iron (Fe) concentration test results in leachate samples if calculated on average per day as listed in table 2 above, the value of Iron (Fe) concentration that occurs only in the third and the second ponds occurs the concentration increase from day 4 to day 7. While in the first storage pond tended to be stable, but when compared with the second and third storage ponds, the first storage pond reached the biggest average value of iron concentration (Fe). The average value of the concentration of iron (Fe) per day is shown in the bar chart in Figure 2 below.

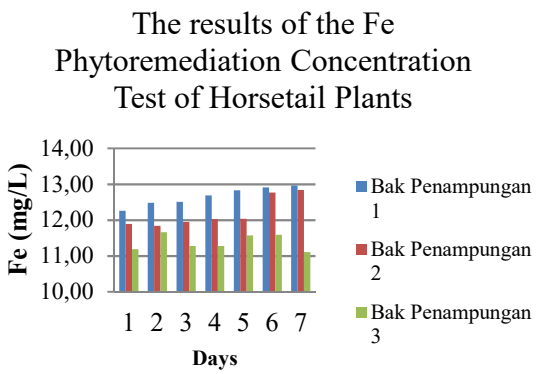

Figure 2. Diagram of the average daily concentration of Iron (Fe) leachate in a phytoremediation pond

Amount of concentration of iron (Fe) leachate in each pond if calculated on average from day 1 to day 7 will get the value of the concentration of iron (Fe) of leachate which can be seen in table 3 below.

Table 3. The average amount of iron (Fe) concentration in the phytoremediation pond

Pond of Phytoremediation Process	Concentration Fe	Unit
Pond 1	12,66	mg/L
Pond 2	12,19	mg/L
Pond 3	11,38	mg/L

Table 3 shows that the lowest average Fe concentration was found in the 3rd phytoremediation pond with an average Fe concentration of 11.38 mg/L whereas the 1st pond with the highest average Fe concentration was 12.66 mg/L. The average amount of Fe concentration in each leachate collection ponds can be shown in Figure 3 below.

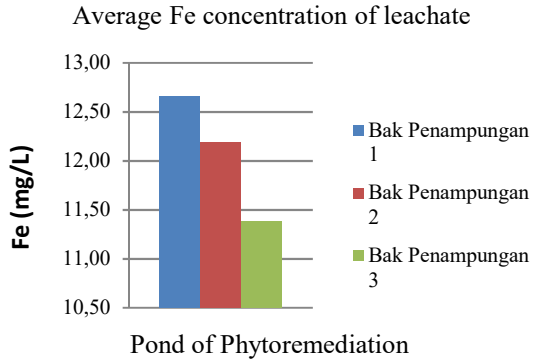

Figure 3. Diagram of average leachate iron (Fe) concentration in phytoremediation pond

The ability of the absorption rate of horsetail plants to Iron (Fe) decreases with the increasement of Fe concentration in leachate. This occurs because of the difference in temperature and air so that it will affect the growth of plants that can no longer absorb optimally. As shown in Figure 3 below, the color changes occurred in some horsetail plants after the 7th day and the appearance of moss in the mud in the leachate treatment pond.

Figure 4. The condition of the horsetail plants in the phytoremediation pond

3.4. Filtration Reactor

The results of testing the amount of iron (Fe) leachate in the reactor pond using zeolite, activated charcoal, and palm fiber can be seen in table 4 below.

Table 4. Test results for the concentration of iron (Fe) leachate in the filtration reactor pond

No.	Day/Date	Sampling	Processing variations in filtration reactor pond	
			Code Sample	Value of the concentration of ferrous metal (Fe) /mg/L
1	Wednesday, 21-08-2019	P_1	F-1.1	11,65
2	Sunday, 25-08-2019	P_2	F-1.2	6,27

Source: Results of regional health laboratory testing, Serang District Health Office 2019

Table 4 shows that the Iron (Fe) concentration test results for leachate in the first collection were 11.65 mg/L, while the results of the second leachate test for the next four days were 6.27 mg/L.

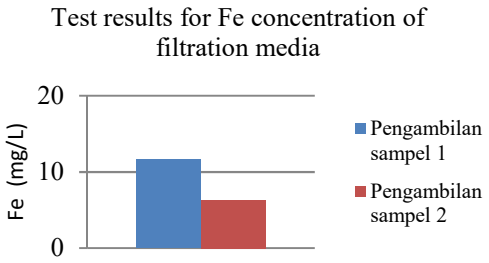

Figure 5. Diagram of test results for Fe concentration of leachate in a filtration reactor pond

Figure 6 shows that the optimization of detention time affects the decrease in Fe concentration of leachate resulting from the filtration media absorption reaction in the reactor pond. The treatment process in the filtration pond is a further process of processing in the phytoremediation reactor pond. With a detention time of 4 days, it can be seen clearly from the results of tests that have been carried out from the second sampling decreased by 45% from the number of the previous sampling. This proves that the addition of the filtering process after the phytoremediation of horsetail plants can reduce the iron (Fe) concentration of leachate water and change the color characteristics of leachate from jet black to golden yellow as shown in Figure 6 below.

Figure 6. Discoloration of leachate samples in a filtration reactor pond

Leachate that comes out through the filtration media begins to show separate particles that are golden brown. As shown in figure 7, the process of sedimentation of leachate in a filter pond containing zeolite, activated charcoal and palm fibers with a detention time of 4 days is carried out to maximize the three filter media binding organic or inorganic substances which are still dissolved in leachate.

Figure 7. Leachate condition in the filtration reactor pond

3.5. Efficiency of the leachate treatment process to reduce the concentration of Iron (Fe)

Efficiency calculations are carried out to find out how much the percentage decrease in Fe concentration in leachate water treatment using phytoremediation of horsetail plants and filtration media. The series of results of testing leachate water samples that have been carried out before treatment and after treatment is shown with the bar diagram in figure 8 below.

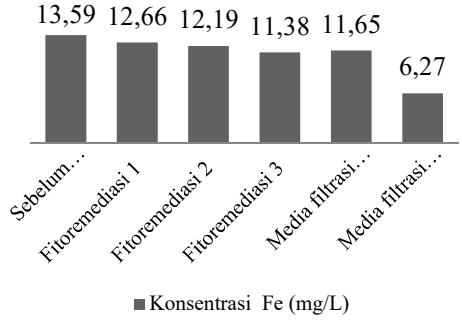

Figure 8. Diagram of test results for Fe leachate concentration

The order of the results of the Fe concentration test from the four complete leachate ponds have been summarized in Table 5 after calculating the efficiency of the treatment process with the equation below.

$$E = \frac{(S_0 - S_1)}{S_0} \times 100\% \quad (1)$$

Table 5. The efficiency of the treatment process to reduce the concentration of iron (Fe) leachate

No	Leachate Sample	Fe Concentration (mg/L)	Efficiency (%)
1	Before treatment	13,59	-
2	Phytoremediation 1	12,66	6,9
3	Phytoremediation 2	12,19	10,3
4	Phytoremediation 3	11,38	16,3
5	Filtration Media (P_1)	11,65	14,3
6	Filtration Media (P_2)	6,27	53,9

Table 6 shows the difference in the amount of Fe concentration and the value of efficiency resulting from the phytoremediation process and filtration media. It can be said that the smaller the value of Fe concentration, the greater the efficiency value produced. Optimizing the effect of the number of horsetail plants on the reduction of Fe concentration of leachate water in the phytoremediation pond of the plants that only obtained a decrease in Fe concentration of 2,210 mg/L from the results of testing of leachate samples before treatment namely 13.59 mg/L by obtaining an efficiency value of 16.3%. This is indicated in the 3rd pond with the highest number of plants, namely 24 horsetail plants. The optimization of the effect of stay time on the reduction of Fe concentration in the filtration media is shown in the second sample with a stay of 8 days which obtained a decrease in Fe concentration of 7.317 mg/L and obtained an efficiency value of 53.9%. Graph of decreasing of Fe leachate concentration and increasing value of processing efficiency can be seen in figure 9 below.

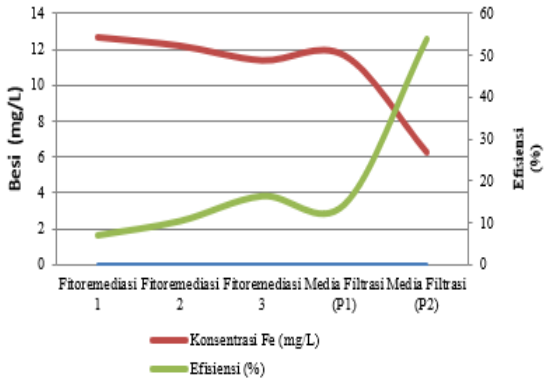

Figure 9. Graph of leachate treatment process efficiency towards decreasing Fe concentration

3.6. Simple Linear Correlation Test

A simple correlation test is performed to determine whether there is a relationship between the value of Fe concentration resulting from the leachate treatment process and the efficiency of decreasing Fe concentration. The formula used to calculate the Simple Correlation Coefficient is as follows.

$$\mathbf{r} = \frac{\mathbf{n\Sigma xy - (\Sigma x)(\Sigma y)}}{\sqrt{\mathbf{\{n\Sigma x^2 - (\Sigma x)^2\}\{n\Sigma y^2 - (\Sigma y)^2\}}}} \quad (2)$$

while the data to be tested with a simple correlation are in table 7.

Table 6. Simple correlation test data with the Pearson formula

N	Leachate treatment process (mg/L)	Efficiency (mg/L)	X^2	Y^2	XY
1	12.66	6.9	160.2756	47.61	87.354
2	12.19	10.3	148.5961	106.09	125.557
3	11.38	16.3	129.5044	265.69	185.494
4	11.65	14.3	135.7225	204.49	166.595
5	6.27	539	39.3129	2905.21	337.953
Total	54.15	101.7	613.4115	3529.09	902.953

Based on table 6 if it is known :

$n\Sigma xy = 4514.765$
$\Sigma x = 54.15$
$\Sigma y = 101.7$
$n\Sigma x^2 = 3067.058$
$\Sigma x^2 = 2932.223$
$n\Sigma y^2 = 17645.45$
$\Sigma y^2 = 10342.89$

then r is :

$$\frac{5(902,95) - (54,15).(101,7)}{\sqrt{\{(3067,06-2932,22)\}.\{(17645,45-10342,89\}}}$$

$$= \frac{4514,75 - 5493,325}{\sqrt{134,84 . 7302,56}}$$

$$= \frac{-978,56}{\sqrt{984677,20}}$$

$$= \frac{-978,56}{992,31}$$

$R = -0,986$
$R^2 = 0,972$

Based on the calculation results, the correlation coefficient between the value of Fe concentration and the value of efficiency is -0.986, which means that the two variables are negatively strongly linear correlated. This means that if the value of Fe concentration decreases, the efficiency value of Fe concentration decreases will increase and vice versa. Thus the contribution of Fe concentration to the efficiency of 97.21%, which means 97.21% leachate treatment processes gave contribution to the efficiency value of the system.

4. Conclusion

The selection of leachate treatment through phytoremediation using Horsetail Plant (Equisetum hyemale) and the filtering process with zeolite, activated charcoal and palm fiber as an advanced process based on consideration of the use of biological biota and simple wastewater treatment technology in leachate is an effort to reduce the level of environmental pollution caused by the leachate water.

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