Effectivity of constructed wetland using *Typha angustifolia* in analyzing the decrease of heavy metal (Fe) in acid mine drainage

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Abstract. Coal mining in Indonesia mostly done by open mining. The most severe problem in open mining activities is Acid Mine Drainage (AMD) production. Acid mine drainage contains heavy metal (Fe) that will impact now and future living creatures. One of the increasing of acid mine water treatment after the mining process is by using a constructed wetland method. This research aims to analyze constructed wetland effectiveness with rate variation, the number of plants, and material composition (compost, gravel, and limestone). The aims are also to examine local plant of Tifa (*Typha angustifolia*) ability on decreasing heavy metal (Fe) of acid mine drainage according to Kaltim Regulation Number 02 the year 2011 on water quality standard of coal industries. The study used the method of constructed wetland using a surface flow system, and a vertical ascending flow operated continuously using the elevation. The built wetlands design uses an intermediate bulk container tank with 100 cm x 100 cm x 100 cm reactor dimension. The result shows that the decrease of the efficiency acid mine water on surface flow constructed wetland for Fe as follows in a row 70.88% (reactor 4), 57.88% (reactor 2). The best Fe metal content absorption is obtained on plant amount 15 treatment with 0.001 L/s rate, with iron content absorption 3294 ppm (40.11%). Fe metal content decrease on compost is obtained to 20% compost treatment with 0.001 L/s rate, with iron content decrease 8728 ppm (89.23%).

1. Introduction

Most of the coal mining in Indonesia is carried out by open mining (open pit mine). The most severe problem in mining activities publicly mine acid water that is produced. Acid Mine Drainage (AMD) formed by the process of stripping a layer of soil and rock cover (overburden) to found the coal outcrops. Therefore, the water is contaminated with acid mine drainage containing metal in high concentrations can poison the aquatic organisms [1]. World coal prices declining it is feared will cause much land that will be abandoned coal mine and does not do the management environment, including acid mine water management. Problems of mine acid water not only will be faced in the present, but it will still be a serious environmental problems in the future [1].

The method of active treatment are more widely used in mine acid water management with lime. This method has the disadvantage that is cost prohibitive and should add alkaline materials continuously [2]. One of mine acid water treatment technology that is the technique of passive treatment system with a constructed wetland or wetlands. Constructed wetland wastewater treatment system that uses simple technology with the help of processing in sedimentation, filtration, adsorption, gas transfer, and chemical processing [3]. Rationale research this is a merger of the two ponds constructed wetland applied PT Berau Coal into one with surface flow is up the system using the Tifa
plants (*Typha angustifolia*). With the increase of the effectiveness of efforts consider the artificial Marsh with the addition of anoxic limestone, gravel or substrate material.

The purpose of this research is to analyze the effectiveness of vertical surface flow constructed wetland with the variation of discharge, the number of plants, and the composition of the material as well as analyzing the ability of local plants namely *Typha angustifolia* in lowering heavy metals (Fe) contained in mine acid water.

2. Methods

1.1. Time and location research

This research was carried out in February-June 2016. Sampling and analysis metal concentrations of Fe in acid mine water is performed in the laboratory of acid mine drainage PT. Berau Coal in East Kalimantan while metal concentration analysis of Fe in the tissue of plants and compost media done in Study Hall Agricultural Technology, Maros, South Sulawesi.

1.2. Data collection techniques

This research was conducted in a laboratory-scale with experimental research methods, i.e. grappled to see the influence of the variables examined. The control variables used or became control is a condition existing with $Q = 0.0008929 \text{ l/s}$, the amount of 100% crop and composition based on constructed wetland Q8 Lati Mine Operation PT. Berau Coal is converted to a pilot project that is 50% of the height of the reactor (50 cm) so that the Limestone = 17 cm, 6 cm of Sand and organic (compost) = 27 cm, with the number of 100% crops Tifa (*Typha angustifolia*). As for the research of the variable as follows:

Variation I: debit flow (Q)

$Q1 = 0.00125 \text{ l/s} \text{ (residence time 5 days)}$

$Q2 = 0.00200 \text{ l/s} \text{ (residence time 3 days)}$

Variation II: the number of plants (JT)

$JT1 = 50\% = 15 \text{ plants}$

$JT2 = 100\% = 30 \text{ plants}$

Variation III: composition (K)

$K1 \text{ Gravel } = 5\%, 15\% \text{ limestone, compost + soil } 30\%$

$K2 \text{ Gravel } = 10\%, 20\% \text{ limestone, compost + soil } 20\%$

1.3. Tools and materials

The tools and materials used in this research are reactor, the connection pipes 1 "dop, pipe 1" pipe elbow 1 ", Valve pipe Connections 1" T 1 ", Jerry/bucket, drill, Glue the pipe, hacksaw, 100 ml measuring cup, and the meter and a slide rule, a profile of the tank, limestone, sacks of compost + soil, gravel, Tifa (*Typha angustifolia*), acid mine water inlet sediment pond water monitoring point 16. Table 1 below shows the characteristics of *Typha angustifolia* plant where appropriate with research [2].

2.4. Constructed wetland reactor

The main tool used in this research is a continuous vertical flow reactor. Reactor constructed wetland made from fiber-plastic/box with dimensions 100 cm x 100 cm 100 cm. In this research will be used 8 fruit cultivated reactor Tifa (*Typha angustifolia*) with different design variations. One fruit of the reactor control that refers to the condition of the existing constructed wetland Q8 site lati mine operation PT Berau Coal at the site. These tools combined parallel tank toward a profile of reactors using different height to regulate debit chill and plastic tubs that is associated with a pipe. On the pipe inlet or outlet is connected to in a given valve that serves to set the entry of water from the profile to reactors.

2.4.1. Phase of acclimatization. The purpose of this stage of the test plants in order to be able to adapt to the environmental conditions place of experiment. The process of acclimatization is done by way of planting herbs for 2 weeks on the media compost using water-neutral to customize the plants in order to be stable. The measurement of physical characteristics on growing media and plants performed to
find out the content of iron (Fe) metal found in the ground prior to contamination by acid mine wastewater.

Table 1. Characteristics of *Typha angustifolia*.

| No. | Characteristic                      | Description          |
|-----|------------------------------------|----------------------|
| 1   | Physical Condition                 | Fresh and no yellowing|
| 2   | The number of Stems (strands)      | 5 -10                |
| 3   | Height (cm)                        | 100 – 120            |
| 4   | Width (cm)                         | 3 – 5                |
| 5   | Planting distance (cm)             | 15                   |
| 6   | Planting depth (cm)                | 30                   |

2.4.2. *Operation of constructed wetland*. The selected plant samples respectively, are included within the research reactor contains wastewater from three variations of discharge, composition as well as residence time (residence time). The constructed wetland has a type surface vertical flow system, where wastewater flows slowly and continuously through the gravel, limestone and plants grown in media of compost. Each tub is given three variations, namely debit treatment, and composition. For control = 50% of the height of the tub (50 cm) so that the Limestone = 17 cm, 6 cm of sand and organic (compost) = 27 cm, with the number of 100% crops. For a variation of discharge trough containing the plant carried out the treatment, Q1 = 0.00125 L/s and Q2 = 0.0020 L/s and JT 1 = 50%, JT 2 = 100% whereas for the variation of the composition consists of two treat K1 = 5% gravel, limestone 15%, compost + soil 30%, K2 = gravel, limestone 10%, compost + soil 20%. The process of the constructed wetland was done during 20 days stationed on 3R workshop with the goal of keeping the plants get enough sunlight for growth and avoid the rainwater that can affect the dilution concentration.

The sampling method used in this research is the instantaneous sample i.e. the sample taken directly from a single point at a specific time. Water samples are taken at the beginning of mine acid drainage in the tank at the end of the stream and influent on each reactor constructed wetland in addition also measured soil and plant at the beginning and end of the study. To know the influence of plant growth patterns with the efficiency of processing, then the plant growth observed and measured during the study took place. The observed plant growth is the high number of plants and rods. Furthermore, each media sample plants and plants in a test of using the Atomic Absorption Spectrophotometer (AAS) and for acidic mine in the test with portable data logging spectrophotometer. Based on the results of the laboratory tests carried out analysis and graph using software excel to compare data available.

3. Results

Based on the research conducted, the results of the analysis are as follows:

3.1. Percentage effectiveness of metallic Fe allowance

Laboratory test results data then note the effectiveness of metal stage iron (Fe) based on the formula below can be seen in figure 8. Based on figure 8 graph indicating that the percentage of allowance for experience fluctuations for all reactors but the highest percentage reductions indicated on the reactor of 4 amounted to 70.88%. The metal stage on leachate using constructed wetland, where constructed wetland in vertical flow using a smaller debit i.e. 18.5 ml/ minute rate efficiency allowance ferrous metals reached 95.44% [4]. So with smaller discharge and the residence time is longer than the elimination of heavy metals, pH, as well as organic material more optimally.

The liquid waste treatment system with a subsurface flow constructed wetland (*Typha angustifolia*) using characteristics plant spacing 15 more optimal and nutrients mobility in its vegetation. For the use of compost by volume and greater height resulting in the presence of the addition of organic material so that the presence of microbial growth and reducing bacterial sulfate which can help to lower the pH and cause the dissolved metals on bodies of water, so the concentration of ferrous metals can be lowered [4].
Figure 1. The effectiveness of opt-out metal concentration of iron (Fe).

3.2. Metallic Fe allowance by the media compost

After the operation of the reactor for 9 days, medium soil from each of the reactors analyzed the metallic content. Soil samples were taken from the reactor in random order. As for the data concerning the weight of wet and dry weight in the media compost as follows.

Table 3. Wet weight and moisture content at each reactor.

| Reactor | The design of the | Weight (g) | The Final Weight | Moisture content |
|---------|-------------------|------------|------------------|-----------------|
|         | The design of the |            | wet (g)          | dry (g)         |
| 1       | Q1JT1K1           | 76.13      | 147.28           | 26.95           |
| 2       | Q1JT1K2           | 76.13      | 102.52           | 48.23           |
| 3       | Q1JT2K1           | 76.13      | 142.86           | 32.45           |
| 4       | Q1JT2K2           | 76.13      | 135.50           | 53.91           |
| 5       | Q2JT1K1           | 76.13      | 158.29           | 32.55           |
| 6       | Q2JT1K2           | 76.13      | 136.27           | 55.06           |
| 7       | Q2JT2K1           | 76.13      | 138.29           | 44.35           |
| 8       | Q2JT2K2           | 76.13      | 137.25           | 43.39           |
| CONTROL | CONTROL           | 76.13      | 106.80           | 49.02           |

Based on table 3, visible that the weight of the final composted increased due to the volume of water and the treatment given, where heavy early in the get measurements of weight of compost before use. Water deficit that directly affects the vegetative growth of plants so that the needs of water in plants can be supplied through the soil by way of absorption by the roots [5]. The magnitude of the water that is absorbed by the plant roots are very dependent on the water content and the environmental conditions on the ground. The percentage decrease in the metals iron (Fe) by planting Media concentration with the beginning and end of the metal from the soil medium is shown by figure 2 below. Absorption by Typha angustifolia resulted in a decrease in the concentration of ferrous metals on the compost media, where a decrease in the metals iron (Fe) the highest occurred in reactor treatment of 4 with K2 = 20 cm height of the composting plant, the number 15 with debit 0.00125 L/s decreased by 89.23% of 9782 ppm be 1054 ppm. As for the metal Manganese the highest loss occurred at reactor 2 with K2 treatment = 20 cm height of the compost, the amount of 30 plants with discharge 0.00125 L/s decreased by 80.8% of 472 ppm into 94 ppm.

The decline occurred in all these reactors indicates that for each reactor undergoes absorption in plants which are quite optimal, the percentage decrease varies due to factors on plant nutrition intake of different compost and also genetic factors that cannot be predicted. The influence of compost was instrumental in the accumulation of this metal visible distinction between the stage effectiveness of metals. The reduction of metal can take place through the process of microbial anaerobic, while using the terminal electron acceptors as metal [4].
Measuring results against metal concentrations indicated a decline between before and after the treatment is done. This is certainly going to affect the value of the concentrations of metals in mine acid water that the reduced state doesn't all stay in solution, that only 1-5% are as a metal dissolved, most are in solid shape [1].

![Graph showing Fe percentage in different reactors.](image)

**Figure 2.** Metallic Fe allowance on planting media.

### 3.3 The effectiveness of metallic Fe absorption by plants of *Typha angustifolia*

Absorption of metallic iron (Fe) can be seen in the table below which is the amount of metal contained in each organ of the plant *Typha angustifolia*. From table 4 below, look that in general most ferrous metals contained in the root while the metal manganese, there is a lot on the stem. This depends on the metal manganese translocation ability faster than iron. The heavy metal manganese (Mn) accumulated in the organs of plants.

| Reactor | The design of the  | Heavy iron Fe (ppm) | Total |
|---------|--------------------|---------------------|-------|
|         |                    | In the root | In The Trunk |       |
| 1       | Q1JT1K1            | 2947        | 315        | 3262  |
| 2       | Q1JT1K2            | 2655        | 196        | 2851  |
| 3       | Q1JT2K1            | 2758        | 289        | 3047  |
| 4       | Q1JT2K2            | 3859        | 319        | 4178  |
| 5       | Q2JT1K1            | 2634        | 163        | 2797  |
| 6       | Q2JT1K2            | 2358        | 136        | 2494  |
| 7       | Q2JT2K1            | 2173        | 134        | 2307  |
| 8       | Q2JT2K2            | 2655        | 160        | 2815  |
| CONTROL | CONTROL            | 2079        | 53         | 2132  |

The highest metal content is contained in the root than the organs of the upper part. Only a handful of the top organs contribute to absorbing metals [2]. This is due to direct contact with the roots of acid mine water containing metal while the organ at the top relies on translocation, where the ability of any translocation of metals in plants varies. This item will only be found in old leaves. The Green stems and leaves can accumulate high concentrations of Fe and classified easy translocate to the top of the plant.
Table 5. Measurement of the absorption of metallic Fe on Typha angustifolia.

| Reactor | The design of the reactor | Land The beginning of the | Plant The beginning of the | The end of the | The percentage of Absorption (%) |
|---------|---------------------------|---------------------------|---------------------------|--------------|---------------------------------|
| 1       | Q1JT1K1                   | 9782                      | 254                       | 3262         | 30.75                           |
| 2       | Q1JT1K2                   | 9782                      | 254                       | 2851         | 26.55                           |
| 3       | Q1JT2K1                   | 9782                      | 254                       | 3047         | 28.55                           |
| 4       | Q1JT2K2                   | 9782                      | 254                       | 4178         | 40.11                           |
| 5       | Q2JT1K1                   | 9782                      | 254                       | 2797         | 26.00                           |
| 6       | Q2JT1K2                   | 9782                      | 254                       | 2494         | 22.90                           |
| 7       | Q2JT2K1                   | 9782                      | 254                       | 2307         | 20.99                           |
| 8       | Q2JT2K2                   | 9782                      | 254                       | 2815         | 26.18                           |
| CONTROL | CONTROL                  | CONTROL                  |                            |              | 19.20                           |

From the table 5 above the visible presence of absorption by plants Tifa (Typha angustifolia), where treatment with K2 = 20 cm height of the compost, the amount of 15 plants with discharge 0.00125 L/s in particular at reactor 4 is more effective in helping roots tifa absorb the metals iron (Fe) i.e. of 4178 ppm with percentage of 40.11%. For all reactor occurs the absorption but the amount of metal that is absorbed in smaller as well as plant on less than optimal absorption control reactors namely 19.20% caused by the factors of the number of plants more of 30 plants, thus the intake of a nutrient is less fulfilled and also genetic factors plants that are unpredictable. The above figures 2 indicate that most metals are absorbed by the plants that exist in reactor 4, it is also shown in figure 2, which shows the efficiency percentage rate based on the measurement of metallic mine acid water Fe 4 reactor contained on the largest i.e. of 70.88%. Based on this research, reactor 4 is more effective in reducing levels of ferrous metals in acid mine water using constructed wetland.

4. Conclusion
Based on the research results obtained can be concluded that:

- Application of constructed wetland method proved to be able to raise the pH and metal Fe absorption in accordance with raw quality.
- Constructed wetland method proved effective in raising the pH and Fe metals absorb of 70.88% at reactor 4.
- Method of constructed wetland in the absorption by Tifa (Typha angustifolia) on metal in iron (Fe) 40.11% of reactor 4, whereas in the planting medium drop in metals iron (Fe) amounted to 89.23%. Overall, the metal contained in the plant is largely accumulated in the roots of plants.
- Method of constructed wetland with the combination treatment of discharge, the number of plants, and the composition of material influence on the increase in pH, decrease in the metals iron (Fe).

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