Gold water treatment, waste monitoring, and management with the fitoremediation method

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Abstract. Gold processing activities along the Ciherang river use Mercury. Monitoring and managing the impact of gold processing activities on the environment by the standard quality of wastewater quality of the Ministry of Environment No.202 Th.2004 concerning Wastewater Quality Standards for Gold and or Copper Ore Processing Activities. Monitoring the quality of wastewater flowing into the river by observing water pH, TDS, and mercury content. Environmental management is carried out by reducing the mercury metal content in wastewater, with the phytoremediation method using Eichhornia Crassipes. Monitoring is carried out at five different locations, wastewater out of gold processing, 2 locations at the settling pond, and 2 locations at the river water. The results showed an increase in mercury content in settling pond 2, 0.525 mg / L, and settling pond 3, 0.00903 mg / L. The environmental management with the fitoremediation method day 0 Hg levels of 0.06284 mg / L, day 4 Hg levels produced to 0.01203 mg / L, day eight the value of Hg levels 0.114 mg / L, the 12th day the value of the resulting Hg 0.01267 mg / L

1. Introduction
With the existence of several gold mining sites in the district Kutawaringin, Bandung, which in its processing using the settling pond. From a previous study entitled “Analysis of Wastewater Treatment Results of the Multipurpose Cooperative Gold Cooperative in Kutawaringin Village, Kutawaringin District, Bandung Regency, West Java Province [1]. It can be proven that to clean or reduce the concentration of mercury in wastewater resulting from gold processing, treatment can be used in the form of water hyacinth (Eichhornia Crassipes). The treatment using by high mercury concentrations or not in accordance with the quality standards of wastewater in settling ponds can occur a significant decrease so that when flowed into the river the concentrations contained in treated water are in accordance with water quality standards waste and will not harm the surrounding environment and public health. It needs the study of the implementation of phytoremediation using Eichhornia Crassipes on the settling pond before flowing into the river. In order to be suitable with the quality of the water, which has been regulated by Decree of the Minister of Environment No. 202 the year 2004 on The Quality of The Wastewater for Gold/Copper Ore Mining Activities and Decree of the Minister of Environment No. 5 the year 2014 about Quality of Wastewater.

To prevent high-concentration Mercury flowing into the river and the spread of diseases caused by high mercury concentrations, one of the methods to reduce it by using water hyacinth. This type of plant able to absorb heavy metals. The density of Eichhornia Crassipes depends on the size and measurement
of it, whereas the larger the size of Eichhornia Crassipes to lower the concentration of Mercury, the faster also the absorbance process. Some factors affect the absorption rate of water hyacinths, such as the condition of metal in water, temperature, and pH.

The purposes of this research are:

- To find out the mercury levels that exist in the Gulundung, Settling Pond 2, and 3 on Day 0.
- To find out how much Eichhornia Crassipes need for test media that has a dimension that will later be used on a field-scale to reduce mercury levels.
- To find out the changes before and after the existence of Eichhornia Crassipes on test media on day 0, 4, 8, and 12 by using the parameters of color and smell in the wastewater.
- To find out the decline in mercury levels in the Settling Pond 2, with many water hyacinths referring to preliminary experiments using test media on day 0, 4, 8, and 12.

2. Theoretical framework

2.1. The usage of Mercury in gold processing

Mercury (Hg) is a metal element that is very important in technology in the new century. Mercury is an element which its atomic number is 80, and its molecular mass is 200.59. The chemical symbol Mercury is Hg, which is an abbreviation from Hydrargyrum that comes from the Greek language and has the meaning of silver fluid. The physical and chemical forms of Mercury are very beneficial. Because it is the only liquid-shaped metals in room temperature (25°C), the lowest melting point is (-39°C), which has a more significant evaporating tendency and quickly mix with other metals to become a mixed metal (Amalgam). It is also able to distribute the electric current as a conductor of both high and low-current voltage.

2.2. Method amalgamation for Gold processing

Amalgamation is the process of extracting gold by mixing gold ore with Mercury (Hg). Mercury will form an amalgam with all metals except iron and platinum. Amalgamation will be useful in fully liberated or partially liberal gold at a particle size larger than 200 mesh (0.074 mm). The three primary forms of amalgam are $\text{AuHg}_2$, $\text{Au}_2\text{Hg}$, and $\text{Au}_3\text{Hg}$.

2.2.1. Direct amalgamation

![Figure 1. Direct amalgamation process.](image)
The experiment process conditions have set as follows: the weight of gold ore is 20 kg, heavy media milled 9.6 kg, mercury weight is 150 gr, pH pulp 9-10, amalgamator swivel velocity on ore smoothing is 55 rpm. An amalgamation period of 9 hours (Mercury is putting together in the grinding process).

2.2.2. **Indirect amalgamation**

![Indirect amalgamation process](image)

**Figure 2.** Indirect amalgamation process.

The experiment condition is the same as the direct one. The difference in this indirect way is the gold ores have not directly inserted into the amalgamator, but there was a washing process to ore gold or getting through two processes.

2.3. **The decreasing mercury levels using Eichhornia Crassipes**

Eichhornia Crassipes belongs to the Pontederiaceae family. This plant lives in tropical and subtropical areas. Eichhornia Crassipes have classified as waterweed that can adapt to environmental changes and breed rapidly. The ideal growing place for Eichhornia Crassipes is shallow and murky water, with temperatures ranging between 28-30°C and the pH conditions ranging from 4-12. In the deep waters and clear waters on the plateau, this plant is difficult to grow. Eichhornia Crassipes can absorb water and vaporize it to air through the evaporation process [2].

Eichhornia Crassipes has advantages in photosynthesis activities, oxygen supply, and absorption of sunlight. The wall section of the root surface, the stem, and the leaves have a receptive coating so that at extreme depths up to 8 meters below the surface of the water, the plant is still able to absorb sunlight as well as substances that dissolve beneath the water surface. The roots, stems, and leaves also have air pockets that can float in the water [3]. Another advantage of Eichhornia Crassipes is that it can absorb nitrogen and phosphor from polluted water, and it becomes the potential to use as a significant component of wastewater cleaners from various industries and households [4].

Eichhornia Crassipes Plant is having the potential to become the waters cleaning material from metal waste and lowers the level of toxicity contained in the waste. Eichhornia crassipes may decrease the Biochemical Oxygen Demand (BOD) particle suspension (in a somewhat slow) basis and able to well-absorb heavy metals such as Cd, Ni, Na, Cr, Pb, Hg, Cu, Ca, Fe, Mn, Zn.

The absorption and accumulation of heavy metals by plants can have divided into three continuous processes, which are the absorption of metals by the roots, translocation of metals from the roots to
other parts of the plants and localization of metals in certain parts of cells to keep it is not detain the metabolism of those specific plants [5].

2.4. The effect of Eichhornia Crassipes density on heavy metal absorption

The density of plants will affect the growth and evaporation process as it will affect the evaporation process and the organic substances that will be absorbed. Plant density also affects the concentration of heavy metals, as more root amounts will affect the rhizofiltration process of plants. The longer its contact, the higher its absorption of contaminants in the water samples until the saturated point limit of the plant performs the absorption process because the plant will have more chances to absorb the metal or the contained elements in the water (Eichhornia Crassipes also performs tolerance and detoxification by accumulating heavy metals in vacuoles in their cell structures. The vacuole is a safe place to accumulate metals because the vacuole is an area far from metabolic processes [6].

2.5. The influence of Eichhornia Crassipes on the surrounding environment.

In the shallow waters, especially the muddy area, Eichhornia Crassipes grows better than in deep waters. It is closely related to the nutrient content in the mud, which is higher and more easily absorbed by plants than in the deep waters. On the other side, Eichhornia Crassipes also affects the surrounding environment of the waters. Such as being able to inhibit the flow of moisture, accelerate the silting up the process because it can hold the particles contained in the water, fertilize the waters with its organic garbage, so it allows the growth of other crops and the source of various diseases, such as mosquitoes. The environment becomes less clean, especially water becomes dirty [7].

Decree of Environment Minister No 202-year 2004 about quality wastewater and gold ore and copper processing.

Table 1. Quality standard for wastewater treatment of Gold Ore and Copper Or.

| Parameter | Unit  | Content | Method of Analysis |
|-----------|-------|---------|--------------------|
| PH        |       | 6-9     | SNI 06-6989-11-2004|
| TDS       | mg/L  | 200     | SNI 06-6989-27-2005|
| Cu        | mg/L  | 2       | SNI 06-6989-6-2004 |
| Cd        | mg/L  | 0,1     | SNI 06-6989-18-2004|
| Zn        | mg/L  | 5       | SNI 06-6989-7-2004 |
| Pb        | mg/L  | 1       | SNI 06-6989-8-2004 |
| As        | mg/L  | 0,5     | SNI 06-2913-1992   |
| Ni        | mg/L  | 0,5     | SNI 06-6989-22-2004|
| Cr        | mg/L  | 1       | SNI 06-6989-14-2004|
| CN        | mg/L  | 0,5     | SNI 19-1504-1989   |
| Hg        | mg/L  | 0,005   | SNI 06-2462-1991   |

From the table 1, it can have Hg is one of the metals which has high toxicity in the environment and is regulated in the environment by Minister of Environment Decree No. 202 of 2004.

3. The results of research and discussion

3.1. Laboratory test result for wastewater samples

In the process of taking wastewater samples from gold processing at community mines, samples have taken at five sampling points, namely gulundung, settling pond 2, settling pond 3, river point 1, and river point 2 and from the 5 points after the test carried out the results obtained which contained in Table 2, which was then adjust to the Minister of the Environment Decree No. 202 of 2004, concerning Quality Standards for Wastewater Treatment of Gold Or Or Copper Ore.
Table 2. PH, TDS, Hg test results.

| Waste Water Point Sampling | Sample Code | pH  | TDS Mg/L | Hg Content (mg/l) |
|----------------------------|-------------|-----|----------|-------------------|
| Gulundung                  | 1A          | 7.94| 400      | 0.032             |
|                            | 1B          | 7.9 | 390      | 0.00517           |
|                            | 2A          | 7.71| 378      | 0.451             |
|                            | 2B          | 7.67| 384      | 0.525             |
| SP 2                       | Slurry A    | 7.84| 568      | 0.00903           |
|                            | Slurry B    | 7.84| 552      | 0.00472           |
|                            | Slurry C    | 7.71| 588      | <0.00024          |
| SP3                       | 3A          | 7.38| 402      | <0.00024          |
|                            | 3B          | 7.32| 386      | <0.00024          |
| RP 1                       | 4A          | 7.98| 224      | <0.00024          |
|                            | 4B          | 7.99| 228      | -                 |
| RP 2                       | 5A          | 7.91| 234      | -                 |
|                            | 5B          | 7.98| 214      | -                 |

Test results for pH, TSS, and Hg were present in the chart on figure 3, figure 4, and figure 5.

**Figure 3.** Chart of pH test result.

**Figure 4.** Graph of TDS test result.
3.2. The Results of mercury reduction using eichhornia crassipes treatment

First Trial: Using Eichhornia Crassipes in Water Bucket

In the figure 6, experiments of the water bucket, the researcher used one bucket with a volume of 10 L with a dimension of 25 cm x 25 cm x 20 cm as a medium for Eichhornia Crassipes treatment. The researcher did a 1-time experiment and put Eichhornia Crassipes, which required 500 gr/m² with a temperature around 25-27°C and done in a closed place to not has exposed to conditions that can affect the experiment. This experiment has a trial time of 12 days with a time interval of 0, 4, 8, 12 days to perform observations of changes in water's color and smell. The later amount of Eichhornia Crassipes experiment results in this bucket will be a reference for testing many Eichhornia Crassipes in Settling Pond 2.

![Figure 5. Graph of Hg level test result.](image)

![Figure 6. The color and smell of wastewater using Eichhornia Crassipes.](image)

The results of first trial using in water bucket, presented in table 3.

Table 3. The changes in Hg condition using test medium with 500 gr/M² Eichhornia Crassipes first trial.

| No | Treatment | Hg Content | Change of odor  | Change of color |
|----|-----------|------------|----------------|----------------|
| 1  | Day 0     | 0.06284    | Quite stinging | Dark Grey      |
| 2  | 4th Days  | 0.01203    | Slightly sting | Quite Clear    |
| 3  | 8th Days  | 0.114      | Quite stinging | Dark Grey      |
| 4  | 12th Days | 0.01984    | Slightly Sting | Clear          |

3.3. Second trial: using eichhornia crassipes in settling pond 2

In the second trial using Settling Pond 2 as the medium, the amount of Eichhornia Crassipes referred to the first trial. Previously, the first trial used 500 gr/M² with a bucket dimension of 25 cm x 25 cm x 20 cm and a period of 12 days with a time interval of 0, 4, 8, 12. The color and smell were very strong before, and after the first trial, both factors decreased. The smell was not as sharp as before, as well as the color, which turned into a clear one. From the first trial result, the researcher put 16.32 kg/m³
Eichhornia Crassipes into Settling Pond 2. Second trial using Eichhornia Crassipes, showing in figure 7.

**Figure 7.** Eichhornia Crassipes into Settling Pond 2.16.32 kg/m$^2$.

**Table 4.** The test results after using Eichhornia Crassipes Treatment in Settling Pond 2.

| No | Code | Sample | Hg (µg/L) | Hg (mg/L) | Analysis |
|----|------|--------|-----------|-----------|----------|
| 1  | Day 0| 62.84  | 0.06284   | AAS-VGA/SNI |
| 2  | 4th days | 12.03 | 0.01203 | VGA/SNI |
| 3  | 8th days | 114 | 0.114 | 6989.78-2011 |
| 4  | 12th days | 19.84 | 0.01984 |

The result from table 4 are shown in figure 8.

**Figure 8.** Graph of the decline of Hg rate on second trial.

**Table 5.** The Percentage of the decline Hg rate after using 16.32 Kg/M$^2$ Eichhornia Crassipes treatment in Settling Pond 2 – second trial.

| No | Treatment | Value Hg | Decrease | Odor Change | Color Change |
|----|-----------|----------|----------|-------------|--------------|
| 1  | Day 0     | 0.06284  | -        | Sting Quite | Dark gray    |
| 2  | 4th days  | 0.01203  | 80.85%   | Slightly sting | Quite clear |
| 3  | 8th days  | 0.114    | -81.41%  | Sting quite | Dark gray    |
| 4  | 12th days | 0.01984  | 68.42%   | Slightly sting | Quite clear |

From table 5, it can have concluded that the decline is not very significant or stable. The decline from day 0 to day four seen from the test results, and the Percentage is fairly large, but on Day 8, the rate percentage becomes minus, or the level of Hg is rising again even greater than the rate of Hg in the Day 0. It can occur because when the researcher took the sample of wastewater on Day 8, there was a
high Percentage of the Mercury contained in Settling Pond. Because the processing activities before sampling with the high amount usage of Mercury or exceed the use of Mercury in Day 0. On the 12th day, the value of mercury decline significantly, which can have to see from the test results and a large percentage obtained. Therefore, in the experiments of Settling Pond 2, the value of Mercury is produced not under the threshold which is 0.005 mg/L. The mercury level from experiment is not under the threshold due to when the Eichhornia Crassipes plants did the absorption process in the day 4 and 8, it turns on the processing on Day 8 was already done and the amount of Mercury put into medium higher than usual or on Day 8 the level of Mercury should be decreased, instead it increased because the new Mercury appeared from processing activities. This event led to the absorption process of Eichhornia Crassipes is not effective and its result not under the threshold of quality standard of wastewater.

4. Conclusion
Based on the results of this research that has been explained in the previous chapter, it can be concluded that:

- From the test results, the value of mercury levels in Gulundung at Sample 1 (A, B) in the amount of 0.032 mg/L and 0.00517 mg/L, in Settling Pond 2. From Sample 2 (A, B) there is an amount of 0.451 mg/L and 0.525 mg/l mercury. In the Settling Pond 3 in Sample 3 (A, B) the mercury level was 0.00903 mg/L and 0.00472 mg/L.
- Eichhornia Crassipes is needed to reduce the mercury content in the test medium is 500 gr/m².
- In the first trial, the color and smell of water with a time interval of 0, 4, 8, 12 days produced the water which its color changed from the concentrated ash to the clear and its smell changed from stinging to odorless. These factors became initial parameters that mercury rate has decreased if using at least 500 gr/M² water hyacinth.
- The reduction of mercury levels (Hg) in Settling Pond 2 from wastewater processing and using Eichhornia Crassipes treatment with the amount of Eichhornia Crassipes referred to the test scale, which is 500 gr/M² and on the field scale is 16.32 kg/m² with the time interval of 0, 4, 8.12 days. On Day 0, the result of the test Hg rate is 0.06284 mg/L and on the 4th day, the Hg rate dropped to 0.01203 mg/L (80.85%). On Day 8, the Hg rate increased again, and it was higher than Day 0, which is 0.0114 mg/L (81.41%), and the Percentage was higher than Day 4. On the 12th day, the Hg rate decline to 0.01984 mg/L (68.42%).

5. Suggestions
Based on this research, the researcher comes up with several suggestions, as follow:

- It is necessary to create a deposition pool at the appropriate processing place according to the regulation of the Minister of Environment Regulation No. 23 of 2008. Wastewater from gold processing already inlines with the value of water quality standard threshold of wastewater when it streamed to Cihorang River.
- The use of Eichhornia Crassipes on Settling Pond able to lower mercury levels (Hg). It is necessary to have follow-up actions in the application of settling pond, so the wastewater throws into the Cihorang River does not cause environmental damage and danger of living creatures.
- The need for supervision from local governments and socialization on the use of Mercury in the processing of gold, so every processing activity will follow the rules that have been set and not damaging the environment with Mercury.

Acknowledgment
Thanks to LPPM Bandung Islamic University for allowing the research team to conduct this research. To those who have helped, we also thanks

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