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The Ability of Water Plants to Reduce the Level of Mercury Pollution in Water Quality in Irrigation

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Abstract

This research was conducted on July – October 2013 about a mercury analysis which has been performed in Environmental Engineering Laboratory of Engineering Faculty, Andalas University. The level of mercury that is permitted by Government Regulation Republic Indonesia No. 82 of 2001 at the fourth grade for water are at 0.005 mg/l. In that analysis, mercury contents with 0.020169 mg/l at irrigated areas in Batang Hari River. This research aims to find out the ability of water lilies (Salvinia molesta), wood lettuce (Pistia stratiotes), and water hyacinth (Eichhornia crassipes) to decrease the content of water level. This research used experimental methods and the initial content of heavy metals mercury (Hg) by using 0.02 mg/L, 0.06 mg/L, and 0.1 mg/L. The results at decreasing concentrations of heavy metals mercury will be compared with the quality standard of heavy metal mercury at the fourth grade of water. The result showed that water lilies (*Salvinia molesta*), wood lettuce (*Pistia stratiotes*), and water hyacinth (*Eichhornia crassipes*) were able to fix the water quality for irrigation which contaminated heavy metal (Hg). Then, mercury concentration reached a quality standard for irrigation at early concentration 0.02 mg/L during the 15 days and at early concentration 0.1 mg/L during 35 days. From the analysis, it was found that Water hyacinth (*Eichhornia crassipes*) is the best plant to decrease the concentration of heavy metals mercury.

Keywords: Water lilies (*Salvinia molesta*); Wood lettuce (*Pistia stratiotes*); Water hyacinth (*Eichhornia crassipes*); Mercury (Hg); Water quality; Phytoremediation

Introduction

One of natural resources that have an important role in supporting the growth of the plant is water. Water serves as a carrier element of nutrients, assimilation, parts of the plant body and transpiration for the plants. Observing from the water functions, the availability of water must be considered both of quantity and quality. The increasing rate of population growth and human needs for water has caused many negative impacts on the availability and quality of water in the form of pollution and environmental damage. In recent years, the rate of growth of industry and mining in developing countries shows the graph of continuing to rise. Water pollution by heavy metals like Mercury, Lead, Cadmium, Cobalt, Zinc, Arsenic, Iron, Copper and other compounds, originally spread in small concentrations but in its process, it will be accumulated or concentrated so that at certain concentrations it can cause the negative impacts to environment. The common heavy metals like Cd, Pb, Co, Zn and Cr etc. are phytotoxic at both low concentration as well as very high concentration are detected in waste water. If these metals are presented in sediments then these reach the food chain through plants and aquatic animals.

River that has been polluted by industrial waste, mining and house waste contains some elements of heavy metals. Moreover, if it is used to irrigate crops, it will certainly cause the plants that contain heavy metals. From the observation in various rivers in West Sumatra, it can be found that the gold mining content with mercury. One of the causes of environmental pollution by mercury is gold processing tailings disposal which are processed in the amalgamation. From the previous studies, in the district of Dharmasraya, Batang Hari River, it was found that the pollution of Heavy Metal Mercury (Hg) gives the impact to this river due to the process of gold mining, meanwhile, in that area, the river water is a source of irrigation for agricultural land [1].

Heavy Metals Mercury (Hg) is the only metal that is liquid at room temperature. Mercury, both metals and methyl mercury (CH_3Hg_+), typically enters the human body through digestion. It also can be originated from fish, scallops, shrimp, and the contaminated waters. Mercury in metallic form is not dangerous, because it is only 15% that can be absorbed by human body. But, once it is exposed to nature, at under certain conditions, it could react with methane that has been derived from the decomposition of organic compounds to form toxic methyl mercury which contains toxic. In the form of methyl mercury, most of it will accumulate in the brain. Because of the absorption in a great level, in a short time, it causes variety of disorders. Starting from the destruction of the balance of the body, it cannot concentrate with deaf and various other disorders.

Mercury can dissolve and seep into the ground and there is also the entrance to the plant metabolism and accumulates in all tissues of plants that affects the outcome of these plants. It contains mercury in a quite large part, reducing the amount of chlorophyll of green plants, reducing plant growth, impairing root growth and having a function as well damage leaves and lowers production. Remedial that is measured (remediation) on contaminated land is needed as an effort to reduce the impact of heavy metals on the environment, crops and water creatures. There are many techniques that can be conducted to attempt recovery (remediation) of the contaminated land; one of them is Phytoremediation that utilizes water plants as a cleaning agent. Some

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of the plants be able to work as phytoremediation agent such as: water liliess, wood lettuce and water hyacinth. The kinds of these plants are aquatic plants that are found in river, beach, pond, and lake in West Sumatera. These plants has an ability called "hyperaccumulator", relatively endured to all of the contaminator and be able to accumulate at enough tissues. Therefore, in this research, these are the plants that reduce the level of mercury pollution in water quality for irrigation.

Materials and Methods

The tools that are used in the implementation of this study are; plastic buckets, 140 ml sample bottles, MVU (Mercury Vaporation Unit). The materials are ; water, Hg $(NO_3)_2$ 1000 mg/l and water liliess, wood lettuce and water hyacinth, as well as tools and other materials that support during the study. This study aims to test the ability of water plants (phytoremediation to reduce the pollution of heavy metal mercury (Hg) until it reaches the limit of class-4 of water quality or water quality for irrigation. The treatment involved with three water plants as an agents of phytoremediation such as Water lilies (*Salvinia molesta*), Wood lettuce (*Pistia stratiotes*), and Water hyacinth (*Eichhornia crassipes*). The selection of the three water plants is easily on findings on various waters in West Sumatra. This study used laboratory-scale experiments by using three water plants; water liliess (*Salvinia molesta*), wood lettuce (*Pistia stratiotes*), and water hyacinth (Eichhornia crassipes). Levels of mercury (Hg) that will be tested to be lowered by Phytoremediation treatment with three plants are 3 levels of concentration and be repeated 3 times with a 20 cm of depth of solution of 20 cm were 0.02 mg/L, 0.06 mg/L, and 0,1 mg/L.

Water liliess (*Salvinia molesta*), Wood lettuce (*Pistia stratiotes*) and Water hyacinth (*Eichhornia crassipes*) are obtained from the water. Plants are selected based on the same weight and covered the entire surface of the container research. The further testing of water samples would be used as a medium to grow three kinds of plants in the laboratory. It is done to measure whether the water contains Hg. If the sample contains Hg, then it will perform an additional heavy metal Hg concentrations until it reaches to three levels, namely 0.02 mg/L, 0.06 mg/L, and 0,1 mg/L. The next step to insert the solution of heavy metals into a plastic box measuring in 80 × 54 × 50 cm and accordance with the desired of water level at 20 cm. The observations are done every five (5) days until Hg concentrations in the water have reached the quality standard for irrigation, which is 0.005 mg/L. When the water sampling will be conducted, the high level of water in the bucket cultivated as the initial state which is 20 cm.

To investigate the decrease of heavy metal concentration, analysis was conducted from water samples in the laboratory by using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The results of the analysis will be compared to the quality standards for irrigation water. Observations on the study at each treatment is conducted every 5 days to determine the reduction tendency of concentration Hg. The observation will be completed if the reduction in the concentration of heavy metals Mercury has been in the raw water for irrigation. Data which is obtained as a result of decreasing in water pollution by the water lilies (*Salvinia molesta*), Wood lettuce (*Pistia stratiotes*) and Water hyacinth (*Eichhornia crassipes*) would be compared to a quality standards for irrigation. Phytoremediation index calculation (IFR) is done based on data from the treatment. The collected data are calculated to find the declined rate of mercury concentration during the activity. The declined rate of mercury concentrations known as phytoremediation index (IFR) was obtained with formula:

$$IFR = \frac{(\text{initialconcentration- last concentration}) \times 100}{\text{Initial concentration}} \quad (1)$$

Results and Discussion

The sample tests were conducted at the Laboratory of Environmental Engineering, Andalas University. The average concentrations (levels) of heavy metal Mercury (Hg) in the solution (research vessel) with an initial concentration of 0.02 mg/L during the observation can be seen in Table 1.

Days	Water liliess (mg/L)	Wood lettuce (mg/L)	Water hyacinth (mg/L)
0	0.02	0.02	0.02
5	0.018	0.018	0.016
10	0.01	0.008	0.007
15	0.005	0.005	0.001

Table 1: Levels of Hg in solution with initial concentration of solution 0.02 mg/L.

Table 1 shows the average concentration of Hg exists in research containers, with an initial concentration Hg 0.02 mg/L. For all the treatments, the quality standard will be achieved after sampling comes on the 15th day. In the treatment with water lilies and wood lettuce, Hg concentrations remains in the solution was right at the limit of water quality standards for irrigation which is 0.005 mg/L on the 15th day. In the treatment with Water hyacinth plants, Hg concentrations remains in the research container is only 0,001 mg/L on the 15th day or it is far under the limit of water quality for irrigation.

The process of absorption and accumulation of heavy metals by plants gets through three processes, namely metal absorption by the roots, metal translocation from roots to other parts of the plant, and the localization of the metal in certain parts of the plant [2]. The reduction trend in heavy metal mercury (Hg) during the observation of the initial concentration of 0.02 mg/L can be seen in Figure 1.

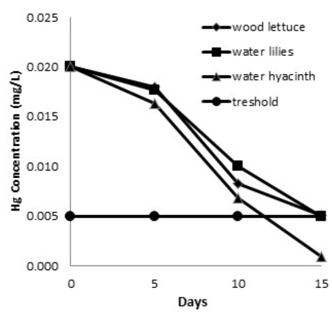

Figure 1: Graph of concentration reduction of mercury (Hg) with initial concentration 0.02 mg/L.

Based on Figure 1, it can be seen that the length of time which is required by Water lilies, Wood lettuce and Water hyacinth to reduce the concentration of mercury (Hg) up to the quality standard limits for irrigation with an initial concentration is at 0.02 mg/L. In the containers of Water liliess and Wood lettuce, it takes 15 days to reach

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the quality of water standard of irrigation and the concentration of mercury (Hg) for irrigation (0.005 mg/L). In the container of Water hyacinth, it takes a shorter than 15 days. Based on the interpolation method, Water hyacinth plants only take 11.67 days to reach below the water quality standard for irrigation. The reduction level of Mercury concentrations then is known as Phytoremediation index (IFR) obtained from the reduction of the initial concentration to the last concentration and it is divided by the initial concentration multiplied by one hundred percent. Phytoremediation index calculation (IFR) is based on data from the treatment. The collected data is calculated to reduce the level of Mercury (Hg) concentration during the activity. The percentage of reduction level of Mercury (Hg) concentration with initial concentration 0.02 mg / L can be seen in Figure 2.

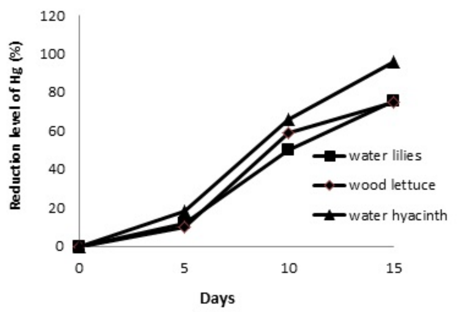

Figure 2: Graph of reduction level percentage of mercury (Hg) concentrations with initial concentration 0.02 mg /L.

From Figure 2, it can be seen that the percentage reduction of Hg concentration with initial concentration of a solution of 0.02 mg/L in the containers of water liliess and Wood lettuce on the 15th day reaches 75% or it is only 25% in the solution. In the container of Water hyacinth plants, it has the highest reduction percentage in heavy metals Hg, where on the 15th day, the percentage of Hg concentrations reaches 96% or it is only 4% left in the solution.

The average concentrations of heavy metals Mercury (Hg) in the solution (research container) with an initial concentration of 0.06 mg/L during the observation can be seen in Table 2.

Days	Water lilies (mg/L)	Wood lettuce (mg/L)	Water hyacinth (mg/L)
0	0.06	20.06	0.06
5	0.049	0.049	0.048
10	0.04	0.037	0.036
15	0.019	0.019	0.018
20	0.008	0.008	0.007
25	0.005	0.004	0.001

Table 2: Level of Hg in solution with initial concentration solution 0.06 mg/L.

From Table 2, it can be seen that the average concentrations of Hg exist in research containers with an initial concentration of Hg is 0.06 mg/L. For all treatments, the quality standard of the samplings achieved on the 25th day and there two of the plants (Wood lettuce and Water hyacinth) achieved the concentration before on the 25th day. In the treatment with Wood lettuce and Water hyacinth, concentrations of Hg in the research containers left only 0,004 mg/L and 0,001 mg/L or already under the limit of water quality for irrigation on the 25th day. Meanwhile, in the treatment with Water lilies, Hg concentrations left in the solution was right at the limit of water quality standards for agriculture (0.005 mg/L) on the 25th day. The reduction trend in heavy metal mercury (Hg) during the observation of the initial concentration of 0.06 mg/L can be seen in Figure 3.

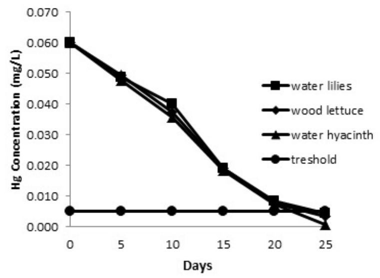

Figure 3: Graph of concentration reduction of mercury (Hg) with initial concentration 0.06 mg/L.

Based on Figure 3, it can be seen that the length of time which is required by Water lilies, Wood lettuce and Water hyacinth to reduce the concentration of mercury (Hg) up to the quality standard limits for irrigation with an initial concentration is at 0.06 mg/L. In container of Water lilies, it takes 25 days to reach the quality standard concentrations of mercury (Hg) for irrigation (0.005 mg/L). In the container of Wood lettuce and Water hyacinth, it takes shorter than 15 days. Based on the interpolation method, the treatment with Wood lettuce takes 23.75 days to achieve water quality standards for irrigation, whereas treatment with Water hyacinth only takes 21.67 days. It means that the treatment with Water hyacinth on the initial concentration 0.06 mg/L is the best treatment in reducing the concentration of mercury (Hg). The percentage of reduction level of Mercury (Hg) concentration with an initial concentration of 0.06 mg/L can be seen in Figure 4.

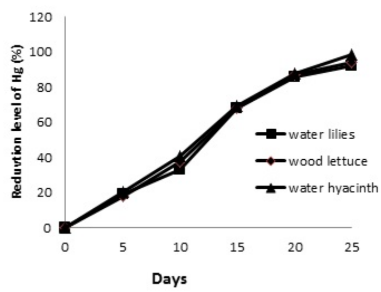

Figure 4: Graph of reduction level percentage of mercury (Hg) concentrations with initial concentration 0.06 mg /L.

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From Figure 4, it can be seen that the reduction level percentage of Hg concentration with initial concentration of a solution of 0.06 mg/L in the containers with water liliess on the 25th day is 92% or 8% remains in solution. In the container with Wood lettuce on the 25th day, it reduces the concentration of mercury (Hg) by 94% and the treatment with Water hyacinth has the highest reduction percentage in heavy metals Hg, which on the 25th day the reduction percentage of Hg concentrations reaches 99% or only it is 1% that is left in solution [3-6].

The average concentrations of heavy metal Mercury (Hg) in the solution (research container) with an initial concentration of 0.1 mg/L during the observation can be seen in Table 3.

Days	Water lilies (mg/L)	Wood lettuce (mg/L)	Water hyacinth (mg/L)
0	0.1	0.1	0.1
5	0.084	0.083	0.08
10	0.075	0.073	0.069
15	0.075	0.073	0.069
20	0.057	0.052	0.049
25	0.032	0.031	0.029
30	0.015	0.015	0.013
35	0.003	0.002	0.002

Table 3: Levels of Hg in solution with initial concentration of solution 0.10 mg/L.

From Table 3, it can be seen that the average concentrations of Hg that exist in the research containers with an initial concentration of Hg is 0.1 mg/L or it is the highest concentration among other treatments. For all treatments, the quality standard is achieved before sampling on the 35th day. In the 25th day, Hg concentrations in container research left only 0.003 mg/L (water lilies), whereas for the treatment of wood lettuce and water hyacinth, concentrations of mercury (Hg) left only 0.002 mg/L in the solution. The reduction trend in heavy metal Mercury (Hg) during the observation of the initial concentration of 0.1 mg/L can be seen in Figure 5.

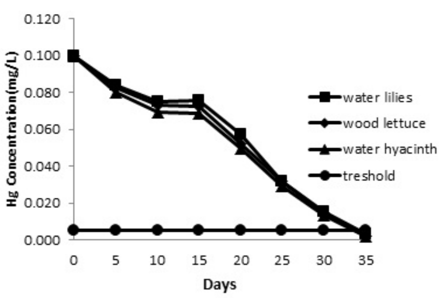

Figure 5: Graph of concentration reduction of mercury (Hg) with initial concentration 0.10 mg/L.

Based on Figure 5, it can be seen that the length of time which is required by water lilies, Wood lettuce and Water hyacinth to reduce the concentration of mercury (Hg) up to the quality standard limits for irrigation with initial concentration is at 0.1 mg/L. In all of the water plants treatment at the time of water sampling on the 35th day, the mercury concentration in the container has been below the quality standard of Mercury (Hg) concentrations for irrigation. Based on the interpolation method, the treatment with the water lilies takes 34.17 days to achieve water quality standards for irrigation, the treatment with wood lettuce takes 33.85 days, whereas the treatment with water hyacinth only takes 33.64 days. It means that the treatment with water hyacinth plants with an initial concentration of 0.1 mg/L is the best treatment to reduce the concentration of mercury (Hg) [7-10].

The percentage of reduction level of Mercury (Hg) concentration with an initial concentration of 0.1 mg/L can be seen in Figure 6.

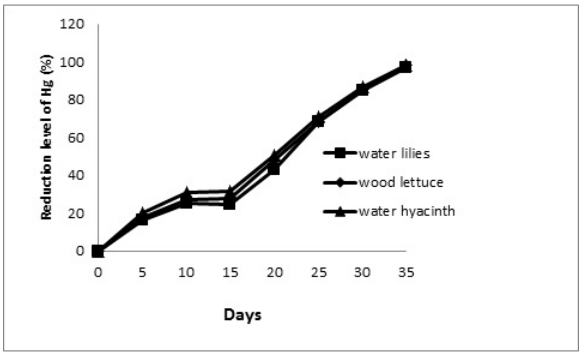

Figure 6: Graph of reduction level percentage of mercury (Hg) concentrations with initial concentration 0.10 mg/L.

From Figure 6, it can be seen that the reduction level percentage of Hg concentration with initial concentration of the solution 0.1 mg/L in the container with water liliess on the 35th day is 97% or remains 3% in solution. In the container with wood lettuce and water hyacinth on the 35th day can reduce the concentration of Mercury (Hg) by 98% or only 2% left in the solution.

Conclusion

Based on the results of the data and the analysis, it obtained some conclusions as follows : (1) The three water plants that were used namely water lilies (*Salvinia molesta*), wood lettuce (*Pistia stratiotes*) and water hyacinth (*Eichhornia crassipes*) could reduce the concentration of heavy metals Mercury (Hg) in achieving the water quality standards for irrigation. (2) Treatment with water hyacinth (*Eichhornia crassipes*) was the fastest plant in reducing the concentration Mercury to achieve water quality standards for irrigation at different level of initial concentration ranging from 0.02 mg/L to 0.1 mg/L, (3) For the treatment with initial concentration of 0.02 mg/L, the treatment by water hyacinth (*Eichhornia crassipes*) took about 11.67 days to achieve water quality standards for irrigation (0.005 mg/L), while for the highest initial concentrations of 0.1 mg/L, water quality standards for irrigation was achieved on 33.64th day. Then, it could be found that water hyacinth (Eichhornia crassipes) was the best plant to decrease the concentration of heavy metals mercury.

Conflict of Interest Statement

There is no conflict of interest in making this article. This is pure of authors and it has been helped on its fund from Andalas University.

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