PHYTOACCUMULATION OF CHROMIUM(VI) METAL ION BY SNAKE PLANT (*Sansevieria tifasciata* Prain)

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Abstrak. Tanaman lidah mertua (*Sansevieria trifasciata* Prain) digunakan sebagai salah satu teknik fitoremediasi untuk menyerap logam krom. Tanaman lidah mertua untuk mengakumulasi ion logam Cr(VI) dari tanah dengan menggunakan variasi konsentrasi pencemar dan variasi waktu. Konsentrasi pencemar yang digunakan adalah 100; 200; 400; dan 800 ppm. Konsentrasi ion logam Cr dapat diukur dengan menggunakan Spektrofotometer Serapan Atom (SSA). Hasil penelitian menunjukkan bahwa akumulasi ion logam Cr(VI) pada lidah mertua paling besar pada pekan ketiga yaitu 6,30 mg/kg berat kering. Jenis mekanisme fitoremediasi yang terjadi pada akumulasi logam Cr(VI) pada lidah mertua adalah rhizofiltrasi. Berdasarkan hasil tersebut tanaman lidah mertua tidak berpotensi sebagai tanaman hiperakumulator terhadap logam krom.

Kata Kunci: Fitoremediasi, Hiperakumulator, Lidah Mertua, Kromium.

Abstract. Snake plant (*Sansevieria trifasciata* Prain) used as one of the phytoremediation techniques to absorb chromium metal. Snake plants (*Sansevieria trifasciata* Prain) to accumulate ion of Cr(VI) from the soil by using variation of pollutant concentration and time variation. Pollutant concentration used were 100; 200; 400; and 800ppm. The concentration of metal ions Cr(VI) that has been absorbed can be determined using Atomic Absorption Spectrophotometer (AAS). The result showed that the accumulation of metal ions Cr(VI) on snake plant biggest in the third week which is 6,30 mg/kg dry weight. Types or phytoremediation mechanisms that occur in the accumulation of Cr(VI) in snake plant is rhyzofiltration. Based on the result of snake plant are not potentially as hyperaccumulator plant of Chrom.

Keywords: Phytoremediation, Hyperaccumulator, *Sansevieria tifasciata* Prain., Crhomium.

INTRODUCTION

One of the main environmental problems is heavy metal contamination. Heavy metals continue to increase due to the continuous use of heavy metals in various industrial and household fields. Heavy metal contamination causes stress on plants that can demage soil fertility so that cropped production decreases (Jeliazko, 2001; Hardiani, 2009).

Some heavy metals that have the potential to pollute the enviroment are lead (Pb), arsenic (As), chrome (Cr), nickel (Ni), cadmium (Cd), copper (Cu), zink (Zn), selenium (Se), dan mercury (Hg) (Chaney, et. al., 1997; Fardiaz, 2008).

According to Machbub dan Mulyadi (2000), the most dominant heavy metals pollute the environment which has exceeded the threshold according to PP no. 82 of 2001 is chrome. Chrome is a heavy metal that essential at low levels and carcinogenic in high quantities (Candra et. al., 2007; ATSDR, 2006).

One alternative and enviromentally friendly method to reduce heavy metal contamination in the enviroment is the phytoremediation method. According to Aiyen (2004) Phytoremediation is a method that immobilizes metals that become contaminants in the soil using plant. The plant is known as a hyperaccumulator plant.

Hyperaccumulator plants are plant that are capable of translating pollutant metal to parts of the plant more than the roots. Some plants have a high ability to accumulate various existing pollutans. The limitation of phytoremediation technique is limitation concentration of contaminants that can be tolerated by plants. Hyperaccumulator plants can accumulate more than 10 ppm (Hg), 100 ppm (Cd), 1000 ppm (Co, Cr, Cu), and 10.000 ppm (Ni and Zn) (Aiyen, 2004; Subroto, 1996).

Hyperaccumulator plants against Cr metal have been found by several researchers such as Muliadi, et. Al (2013) examined the phytoremediation of Cr metal using land water spinach (*Ipomea reptana*) with a concentration of 133.115 mg/kg; according to Hartanti et. al., (2014) water hyacinth plants (*Eichornia crassipes*) found as much as 2.23 mg/L of chrome metal; Putri et. al (2014) plants with several species of *Eichornia crassipes* solm water hyacinth, *Heteranthera peduncularis* and *Monochoria vaginalis* have concentrations of Cr accumulation of 1.5395 Cr; 0.5728; and 0.1057 µg/gr. The results of these studies indicate that at certain concentrations of metal Cr affects plant growth.

Snake plants (*Sansevieria trifasciata* Prain) is one of species of *Sansevieria* plants, including pollution-absorbing plants that are quite effective (Pradipta, 2011). This plant can grow under conditions of little water and sunlight so it is suitable with the tropical climate and has a high adaptability to the environment (Purwanto, 2006). Lidah mertua is able to accumulate heavy metals because these plants contain steroidal saponin compounds, sulfuhidril groups (-SH) and carboxyl groups (-COOH) (Mimaki et. al., 1996; Yusuf et. al., 2015).

Problems regarding heavy metal pollution and the existence of highly supportive phytoremediation techniques, it is necessasary to develop research on the types of plants capable of accumulating heavy metals. The plant used in this study for remediation of Cr metal on the ground was the lidah mertua (*Sansiveria trifasciata* Prain).

MATERIAL AND METHODS

Materials

The materials used in this study were $K_2Cr_2O_7$, soil, seed of Snake plants (*Sansevieria trifasciata* Prain), H_2O_2 30%, HNO_3 (6M), aquades, aquabides, universal pH paper, and Whatman No. 42 filter paper.

Tools

The tools used in this study are basin, flower pot, analytic blancr, oven, desiccator, *hot plate*, *petridish*, mortar, horn spoon, artificial waste making equipment, glassware, and Atomic Absorption Spectrophotometer (AAS), Back Scientific 205 VGP model.

The Procedures

1. Soil Media Preparation

The soil that used in this study was taken from vegetable plantations. The soil is cleared of rocks and roots. Content of nitrogen, phosphate, potassium, chrome (Cr), Cation Exchange Capacity (CEC) and organic matter in the soil were analyzed at the soil science laboratory. The soil is then stirred and aerated for two weeks left.

2. Contaminated Cr(VI) Production

Soil that has been prepared through the drying and stirring stage, added a solution of Cr (VI) as a pollutant at various concentration, there is 100, 200, 400, and 800ppm.

3. Preparation of Plant Media

Some clean pots are filled with 1.5 kg of soil mixed with Cr (VI). The soil is then sprinkled with TSP fertilizer and KCl, then doused with distilled water. Control is done with the same size pot and the same amount of soil but the soil used doesn't contaoin the ions.

4. Planting Snake Plant

Snake plant that age ± 1 month planted in pots that have been provided. Every day, the plants are doused with distilled water. Harvesting is done every week for four weeks. Harvested Snake plant are washed with free mineral water so that they are clean of soil and other objects. Cleanly separated roots and limbs are then stored in a plastic bag and ready to be chemically analyzed.

5. Analysis of Cr (VI) Levels on Leaves and Legs

Methods of analyzing Cr (VI) refers to procedures that have been used by Hummer (2002), Pioterowesk-Cyplik and Csamekai (2005), Nouairi et. al. (2005), Aiyen (2004), and Cave et. al. (2000). Generally, the researchers said that analysis of metal ions contained in organic matter, the wet method is better to use than the dry method.

Clean roots and limbs are aerated for several hours. Than, it was carefully weighed on the petridish who had known their empty weight. Part of the plants is heated in the oven for 24 hours at 80 ºC, then cooled in a desiccator. The dried part of the plant is weighed back so that the weight lost is known as the amount of water contained in the roots and leaves.

This dry sample is then crushed on porcelain mortar. The crushed sample is weighed approximately 0.5 g with an analytical balance. The example was dissolved with 5 mL of 6M HNO_3 and 5 mL of 30% H_2O_2, heated until all the material dissolved completely. The solution is cooled, added aquabides, heated and filtered in hot conditions into a 50mL volumetric flask. This sample solution is regulated by pH using HNO_3 and NaOH until the pH is around 2-3. The solution is crushed to the limit with aquabides pH 2 and shaken until homogeneous. The solution is ready to be measured by Atomic Absorption Spectrophotometry (AAS).

6. Determination of Optimum Accumulation Cr (VI)

In determining the optimum time for absorption of Cr (VI) by the Snake plant, harvest is carried out after the plant is one week old. Subsequent harvests are carried out every week for 4 weeks. Each time the harvest, the Snake plant is cleared from the soil and other impurities, then the roots and limbs are separated and analyzed like procedure E. The optimum time is the time when the maximum absorption of Cr (VI) can be obtained from the curve versus the absorption time.

7. Effect of Concentration on the Amount of Ions Accumulated in the Snake Plant

Determination of the concentration Cr (VI) on growing media in the number of ions accumulated in plants with variations the concentration of Cr (VI) ions are 100; 200; 400; and 800ppm. Then these contaminated soils are planted with Snake plant according to procedure D. Harvesting is done at week 3 according to the optimum time obtained in procedure F. Furthermore, the content of Cr (VI) in the roots and limbs of Snake plant is analyzed according to the procedure E.

8. Mechanism of Accumulation Cr (VI) on Snake Plants

Determination of the mechanism of heavy metal accumulation in plants is carried out according to the procedure of Gosh Singh (2005) by calculating the bioconcentration factor (BCF) and translocation factor (TF) with the following formula:

Bioconcentration Factor

$$BCF = \frac{[M] \text{ pada bagian akar tanaman (mg/kg BK)}}{[M] \text{ yang ditambahkan ke dalam tanah (mg/kg BK)}}$$

$$TF = \frac{[M] \text{ dalam daun (mg/kg BK)}}{[M] \text{ dalam akar (mg/kg BK)}}$$

RESULTS AND DISCUSSION

Introduction Analysis

The nature of the soil is very important to know so that preliminary analysis is carried out to determine the concentration of Cr (VI) in soil and fertilizers before being used as a medium for planting Snake plant. Table 1. shows the Cr metal content of soil and fertilizer.

Table 1. Cr Metal Content in Soil and Fertilizers

Sample	[Cr] mg/kg
Soil	2,94
Compost	20,23
$CaCO_3$ Fertilizers	-

The results of the analysis showed that soil and compost contained Cr, respectively 2.94 and 20.33 mg/kg. In addition to analysis of Cr content, physical and chemical analysis of soil was carried out to determine the level of soil fertility and soil type (Table 2). Some parameters used include soil texture, water content, organic matter content (C), cation exchange capacity and levels of N, P, K. The results of the analysis show that the soil is soil with a texture consistent with the growth of Snake plants. The soil includes the type of sandy clay, otherwise known as alluvial soil. Soil texture is very important for determining soil characteristics, water, stored, pore size and development of plant roots because it affects the speed of water withdrawal, aeration and soil fertility. While the soil pH used is around pH 5.5-8.5 which is a good condition for the growth and development of the Snake plants.

Cation exchange capacity (CEC) is the ability to absorb cations (heavy metals) and the ability to exchange cations between cations present in the soil and solution. The capacity of cation exchangers in the soil used was 19.5 cmol/kg which is a moderate area according to 1986 FAO (17-24 cmol/kg). The content of organic matter affects soil mineral content, physical and chemical properties of soil. The content of organic matter in the soil used C 1.59% and N 0.11% which, according to FAO (1986) are included in the low category (1-1.9%).

Table 2. Physical and Chemical Properties of Soil Used

Parameter Test	**Results**
Sand (% dry weight)	58,00
Dust (% dry weight)	21,00
Clay (% dry weight)	21,00
Water content	5,10
Cation exchange capacity (cmol/kg)	19,58
Content of organic matter (% C)	1,59
N (% dry weight)	0,11
P (% dry weight)	10,40
K (cmol/kg)	0,14

The results of the analysis showed that the soil used in this study contained Cr heavy metals but did not have a negative effect on all vegetables grown at the site. The results of the analysis of the physical and chemical properties of the soil indicate that some test parameters are considered to be eligible for the planting of Lidah mertua, even though the nitrogen content is still low so fertilization with compost and $CaCO_3$ fertilizers is carried out.

Analysis of the Content of Cr (VI) After Accumulation

1. Effect of Harvest Time of Cr (VI) Ions

The amount of Cr (VI) which accumulates on the Snake plant as a function of harvest time is shown in Figure 1.

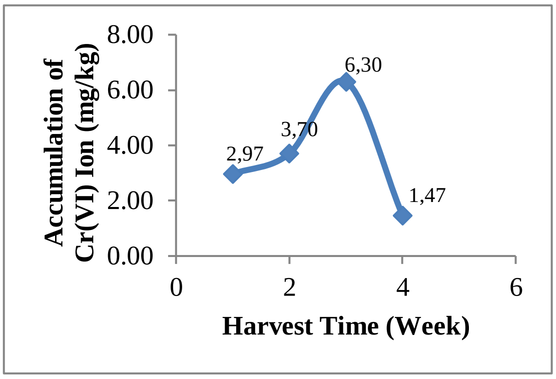

Figure 1. Effect of Harvest Time on the Amount of Cr (VI) Ions Accumulated in Snake plant.

The results of the analysis show that Cr (IV) ions accumulated by the Snake plant in the first week of the fourth week in a row are 2.97; 3.70; 6.30; and 1.47 mg/kg (Figure 1) with maximum accumulation in the third week of 6.30 mg/kg dry weight. In the fourth week the accumulation of Cr (VI) decreased by 1.47 mg/kg because the roots in the plants were no longer able to absorb Cr metal ions on the soil (critical phase). In addition, the Snake plant has experienced physical abnormalities such as chlorosis (yellowing and pale leaves), and withering. This physical abnormality occurs due to nutrient absorption caused by Cr (VI). In general, homoestatic conditions in a living system can tolerate a certain amount of metal concentration without interfering with its growth. But large metal concentrations can reduce detoxification ability so that plants experience impaired absorption and growth.

2. Effect of Concentration on the Amount of Cr (VI) Ions

The amount of Cr (VI) ions accumulated in the Snake plant as a function of ion concentration added to soil media is shown in Figure 2. The accumulation of Cr (VI) in the concentration variations on the growing media shows that the ability of Snake plant accumulation increases with a concentration up to 400 ppm and decreased at 800 ppm with the accumulation of Cr (VI) in a row of 1.96; 2.14; 7.47; and 4.21 mg/kg. Cr (VI) ion is a hard acid so this ion is difficult to interact with phytochelatin compounds that have –SH groups in the plant.

The highest number of Cr (VI) ions that can be accumulated by the Snake plant (7.47 mg/kg dry weight) is obtained at the addition of 400 ppm on the growing medium.

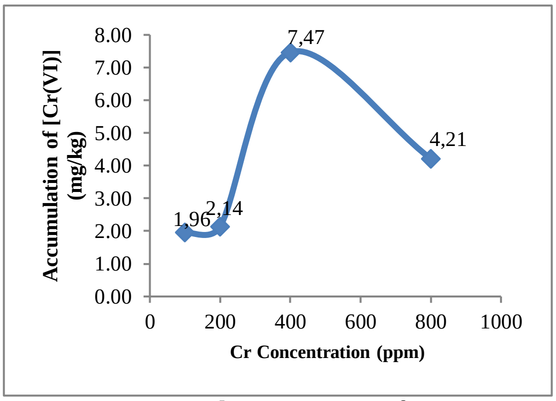

Figure 2. Effect of Concentration on the Amount of Ion-Ion Cr (VI) Accumulated in Snake Plants

3. Absorption Mechanism from Snake Plants

In general, all types of plants are accumulators against metals, but not all plants function as hyperaccumulators. A plant is called a hyperaccumulator of Cr metal if it is able to attract metals in a high enough concentration of 1000ppm (Lasat, 2000).

Snake plant is a type of hyperaccumulator because it contains a protein that has an amine group (-NH2), a carboxyl group (-COOH), as well as a sulfidril group (-SH) which can bind heavy metals.

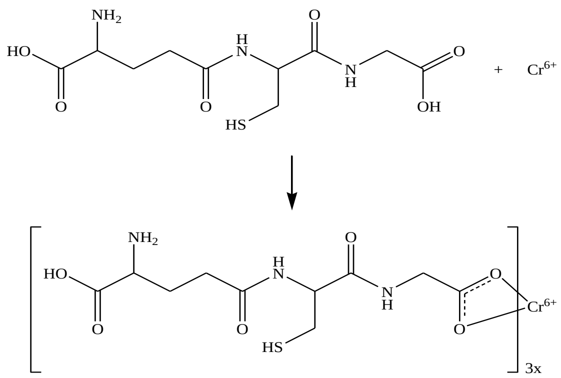

Figure 3. Metal Binding Mechanism in Plants

The results of analysis accumulation of Cr (VI) on soil media, give a value smaller than 1000 ppm in soil contaminated with 100% of Cr (VI); 200; 400; 800 ppm, so that the Snake plant cannot be called a hyperaccumulator plant against chrome.

To determine the mechanism of accumulation of Cr (VI) by the Snake plants, it is necessary to calculate the value of bioconcentration (BCF) and translocation (TF) factors. The translacocation factor (FT) is closely related to the ability to accumulate and translocate metals from the soil to the top of plants. BCF and TF values as a function of Snake plant accumulation of Cr (VI) ions are shown in Table 3.

Table 3. BCF and TF Value

Time	Consentration of Cr Ion	BCF Value	TF Value
First Week	100	0,00	0,98
	200	0,00	0,91
	400	0,02	0,05
	800	0,00	2,20
Second Week	100	0,00	1,01
	200	0,00	0,00
	400	0,01	0,00
	800	0,01	0,09
Third Week	100	0,00	0,00
	200	0,00	4,40
	400	0,02	0,00
	800	0,01	0,00
Fourth Week	100	0,04	0,00
	200	0,00	0,00
	400	0,00	1,01
	800	0,00	0,00

According to Liong et al., (2010) BCF values are generally greater than one, while TF values are generally smaller than one. The BCF value is inversely proportional to the TF value indicating that the Snake plant has the ability to accumulate Cr (VI) ions, but the ability to translocate metals is still low (Yoon et al., 2006). The results of the analysis show that the mechanism that occurs in the accumulation of Cr on the Snake plant is Rhizofiltration.

4. Distribution of Cr(VI) in Snake Plant

Figures 3 and 4 show the distribution of Cr (VI) in the roots and leaves of the Snake plant leaves on variations in harvest time and the concentration of Cr (VI) ions in the growing media. These two images show that in general the concentration of Cr (VI) ions is higher in the roots than in the upper part of the plant. Roots are parts of plants in the soil that interact directly with Cr (VI) ions through rizofer which will form complexes with chelating compounds (organic acids).

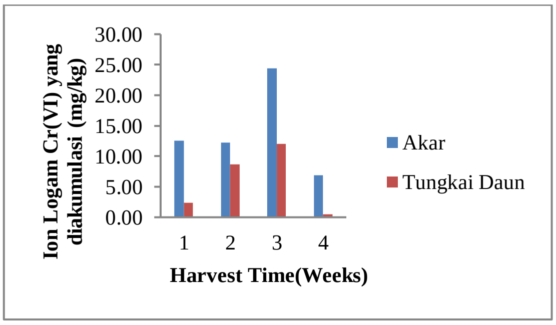

Figure 3. Distribution of [Cr] in the roots and in the leaves vs. Harvest time

The results of this study indicate that in general of the accumulation got the highest Cr (VI) ions is obtained at the root with the average accumulation of Cr (VI) ions as much as 12.51; 12,24; 24,38; and

6.87 mg/kg (especially the third week as much as 24.38 mg/kg) then in the leaves with an average accumulation of 2.33; 8.70; 12.00; and 0.49 mg/kg (Figure 3). The same was found by Muliadi (2013) who used *Ipomea reptana* and Hartanti et al. (2014) who used water hyacinth plants to accumulate Cr (VI) ions.

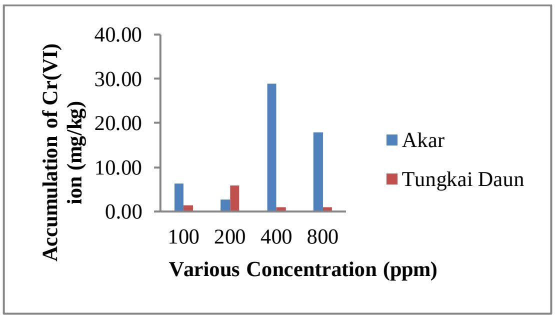

Figure 4. Distibution of Cr(VI) in the roots and leaves vs. Variation of [Cr] on growing media

The results obtained showed that the Cr (VI) ion accumulated the highest in successive roots 6.39; 2.69; 28,92; and 17.87 mg/kg then leaf limbs respectively 1.46; 5.85; 0.97; and 0.98 mg / kg (Figure 4). However, at pollutant concentration of 200ppm, Cr (VI) metal ions accumulated the most in the leaves (5.85 mg/kg) than in the roots (2.69 mg/kg). This is because the metal ion Cr (VI) absorbed in the roots undergoes translocation from the root to the limbs through the transport network of the plant. The difference in metal uptake in plants is caused by the number and surface area of the roots, the height and width of the leaves and the large number of leaves owned by the Snake plant.

According to Lasat (2000), the high accumulation in roots occurs because metals can be complexed and stored in vacuole cell organelles so that it is difficult to translocate to the top of plants.

CONCLUSION

The conclusions obtained from the results of this study are as follows.

1. The Snake plant has no potential as hyperaccumulator plant for Cr (VI) because it is only able to = accumulate metal ions Cr (VI) below 1000 ppm.
2. The accumulation of Cr (VI) metal ions in the Snake plant was the largest in the third week, which was 6.30 mg/kg.
3. The type of phytoremediation mechanism that occurs in the accumulation of Cr (VI) metal ions in the Snake plant is rhizofiltration.

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