Phytoremediation of lead-contaminated soil by ornament plant *Codiaeum variegatum*

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Abstract. Phytoremediation is an emerging technology that employs the use of higher plants for the clean up the contaminated environment, a cost-effective, environment-friendly. In this study, the role of puring (*Codiaeum variegatum*) plants as a potential phytoremediator to soils contaminated with lead (Pb) was investigated. A pot experiment was conducted for four and eight weeks to compare the biomass and lead content in root, stem and leaf by puring. The plant grew well exposed Plants that grow well are exposed to Pb with as much as 250 mg.kg$^{-1}$ and 375 mg.kg$^{-1}$ soil. The result presented here showed that root, stem and leaf biomass decrease with increasing concentration and exposure time. Pb accumulation increases with increasing concentration and time of exposure. Pb accumulation in roots> stems> leaves. Bioaccumulation of factors is less than 1 while factor translocation is more than one. Metal tolerance index values range 95.545% to 103.406%. This suggests that *Codiaeum variegatum* was a candidate for phytoremediation of lead

1. Introduction

Heavy metal pollution is one of the important environmental problems throughout the world. Sources of heavy metals entering the environment are naturally and anthropogenic [1]. Among heavy metals, lead is one of the major heavy metals as a potent environmental pollutant, besides the natural weathering process, the main source lead pollution in the environment are mining and smelting of lead ore, fertilizer, pesticides, and gasoline. Lead is major of the main hazardous substances to the environment and leads contamination in water, air and soil are an ecological problem because its impact is not only inhibiting plant growth decreases such as decreased drying of root and shoot biomass, impaired mineral nutrient, and reduced cell division also affects human health [2]. Lead considered a general protoplasmic toxic, with is cumulative, slow-acting and smooth, studies have shown that lead influence some metabolic activities in dissimilar cell components [3].

The technology used to reduce heavy metal concentrations to environmentally acceptable levels at an affordable cost. Therefore phytoremediation with low-cost materials has emerged as a hopeful
technology for recovering lead from contaminated. Phytoremediation is referred also to as botanical bioremediation which defined as the use of green plants to remove pollutants from the environment or turn it into harmless [4]. The capability to accumulate heavy metals vary significantly between species and between cultivars within a species. Several plant species have been used to remediate lead-contaminated soil such as Alternanthera bettzickiana, Eichhornia crassipes, Coronopus didymus and Oryza sativa [5-9].

Ornamental plants are important if they are hyper-accumulated and can be applied in the remediation of contaminated soils. Ornamental plants provided economic benefits because in addition to beautifying the environment it can also improve the environment at the same time. This one is a specific advantage that differs from ornamental plants with other hyperaccumulator plants, and therehave many advantages such as increase biodiversity, reduce erosion and phytoremediation of some pollutants [10]. All this time, there has been no systematic identification of ornamental plants that apply to the remediated of contaminated soil. In municipal regions, ornamental plants have practical applications in the indicated and precaution of pollution, but also can beautify the environment [10].

In this study, Codiaeum variegatum plants were used for the remediation of lead-contaminated soil. The results of the literature study, have not done much research that reveals the potential of Codiaeum variegatum plants as lead phytoremediation. Research conducted by [11], that the efficiency of lead absorption by Codiaeum variegatum was 15.66% inceptisol soil, so that needs to be investigated further about the potential of Codiaeum variegatum plants in lead accumulation and lead poisoning against plant growth. The aim of this research was to analyze the ability of Codiaeum variegatum to absorb lead and analyze the effects of lead on plant biomass. Codiaeum variegatum has ecological, economic and aesthetic value so as to remediate the level of lead-contaminated and have the ability to tolerate and accumulate lead.

2. Material and Methods

2.1. Material
The soil samples were taken from the Kalisegoro Village, Gunungpati Subdistrict, Semarang City, Central Java, taken with a depth of 0-30 cm and then the soil is air-dried and sieved with a size of 2 mm mesh. The physicochemical characteristics of the soil were: texture lay loam, pH 6.61, 0.44% organic C, P 137.93 mg / 100g, K 13.23 mg / 100g, CEC 16.6 cmol (+). Kg-1, permeability 2.22 cm / hour, air content 11.25%, soil volume 1/18 g / cm3, Specific gravity 2.15 g / cm3 and porosity 45.12% and lead 27.47 mg/kg (Herlina, 2018). All plants with a height of 20 cm were selected for the test plant.

2.2. Plant material and growth condition
C variegatum were used for this study collected from the nursery in Ambarawa. C ariegatum was grown in pot experiments containing 1.5 kg of dry soil and 0.5 kg of vermicompost. After four weeks each pot separately and applied Pb(NO3)2 as much as 250 mg/kg (T1), 375mg/kg (T2) and 27.47 mg/kg (T0) for each treatment with three replications.

2.3. Plant growth measurement
After the plants are four and eight weeks old, the plants are harvested and separated by roots, stems, and leaves. After that, the weight of the stem, leaf, and root measured. Each organ of the plant was dried in an oven for three days at 70°C and measured dry weight.

2.4. Measurement lead content
The roots, stems, and leaves were have dried then ground using mortar and pestle. Add HNO3 and HClO4 solution at a ratio of 9: 4. Lead content is measured by atomic absorption spectrophotometer (AAS, Perkin Elmer A Analyst 400) with a wavelength of 217 nm.
2.5. Analysis of MTI, TF, and BAF

BAF and TF values to determine plant species capacity in the remediation of metal contaminated soil. The value of the Metal Tolerance Index (MTI) was measured by the methods from [12]. The value of the translocation factor (TF) and bioaccumulation factor (BAF) to determine the potential of phytoextraction or phytostabilization are measured by the method [13].

MTI (%) = [(treatment plant biomass) / (plant biomass without treatment)] x 100 ........................................ (1)

TF = (metal content in stem/leaf tissue) / (metal content in root) ................................................................. (2)

BAF = (metal contents in plant tissue) / (metal content in soil) ................................................................. (3)

2.6. Statistical measurement

The research all data were analyzed by one-way analysis of variance (ANOVA) and the treatment mean compared with the LSD test at p ≤ 0.05

3. Result

3.1. Effects of lead on plant biomass

Table 1 presents the effects of lead on Codiaeum variegatum biomass for 4 and 2 months. Lead exposure had a significant effect (p < 0.05) on root dry weight for 1 month and leaf dry weight for 2 months.

Table 1. Table 1. Effect of concentration and time of lead exposure on plant biomass

| Treatments | Root dry weight (mg) | Stem dry weight (mg) | Leaf dry weigh (mg) |
|------------|----------------------|---------------------|-------------------|
|            | 1 month | 2 month | 1 month | 2 month | 1 month | 2 month |
| T0         | 3051 ±671±218 | 3847±296a | 2336±192a | 3217±345b | 4671±283a | 5626±333a |
| T1         | 2808±202a | 3066±266a | 2134±218a | 2735±220a | 3588±385a | 4415±348b |
| T2         | 2474±289b | 2841±133a | 2067±307a | 2544±299a | 3138±294a | 4020±311b |

Different letters indicate that the values differ significantly at p <0.05

During 1 month of lead exposure to root dry weight was highest at 3051 mg. Stem dry weight from 2068 - 2336 mg, while leaf dry weight ranges 3338 - 3671 mg. The dry weight of the stems and leaves is reduced with increasing lead concentration. During 2 month of lead exposure, root dry weight was reduced 9%, while stem dry weight was 10.71% and leaf dry weight was 28.55%, leaf dry weight decreased significantly with control.

3.2. Lead content in plant

Lead content increases with high lead in growth media (Table 2). The lead content in roots is higher followed by stems and leaves. The lead content in stem and leaf roots was significantly different P <0.05.

Table 2. Lead content (mg/kg) in roots, stems and leaves Codiaeumvariegatum

| Treatments | roots (mg/kg) | stem (mg/kg) | leaves (mg/kg) |
|------------|--------------|--------------|---------------|
|            | 1 month | 2 month | 1 month | 2 month | 1 month | 2 month |
| T0         | 10.97±2.37a | 11.94±2.63a | 6.75±1.44a | 7.83±1.43a | 5.79±1.24a | 6.38±2.37a |
| T1         | 57.97±7.50b | 88.54±8.41b | 31.67±5.03b | 40.36±3.22b | 25.65±4.66b | 30.33±6.80b |
| T2         | 67.59±12.23b | 103.67±3.47c | 38.05±6.58c | 49.23±7.22b | 29.77±8.49b | 32.61±5.67b |

Different letters indicate that the values differ significantly at p <0.05

Lead exposure at T1 for 1 month at root increased 81.08%, at stems 78.69%, and at leaves 77.43%, while at T2 lead content at roots increased 83.77%, at stems 82.26% and at leaves 80.55%. During 2 month of lead exposure at T1, lead content in roots increased 86.51%, in stems 80.60% and in leaves 78.96%, while in T2 lead content in roots was 88.48%, in stems 84.10 % and 80.44% in leaves.
3.3. Bioaccumulation and translocation factor

BAF values were higher in shoots (stem + leaves) than roots (Table 3). In this study, the BAF value decreased in line with the increase in lead concentration both at the root and on the stem + leaf. BAF value range is 0.09 - 0.12.

| Treatments | BAF root       | BAF stem+leaf | TF       |
|------------|----------------|---------------|----------|
|            | 1 month | 8 week | 1 month | 2 month | 1 month | 2 month |
| T0         | 0.39±0.086a | 0.42±0.096a | 0.46±0.096a | 0.52±0.123a | 1.53±0.288 | 1.52±0.338 |
| T1         | 0.12±0.023b | 0.15±0.025b | 0.18±0.017b | 0.21±0.03b | 1.62±0.064 | 1.59±0.052 |
| T2         | 0.09±0.024b | 0.12±0.007b | 0.14±0.02b | 0.16±0.022b | 1.68±0.276 | 1.46±0.102 |

Different letters indicate that the values differ significantly at p <0.05

Table 3 shows that the TF value is high along with the increase in lead exposure and the TF value decreases with the time of lead exposure. TF value range is 1.46 - 1.68

3.4. Metal tolerance index (MTI) of Codiaeum variegatum

MTI values in this study were 103.4% at T1 and 95.5% at T2, MTI values of more than 100%, indicating that Codiaeum variegatum plants are high tolerance of lead metal. MTI decreases with increasing lead concentration.

4. Discussion

In this study, the lead treatment decreased biomass of roots, stems, and leaves. Alike response to lead exposure has previously been seen in some plants, decreased dry mass of roots and shoots [14]. The decrease in plant biomass might be related to inhibition of the mitotic index seen with lead. In other studies, it has been reported that lead toxicity inhibits root growth in Sedum alfredii [15], Phragmites australis [16] and Zea mays [17]. The decrease in root length and growth, the amount of root hair under heavy metal pressure, which may have caused lower water absorption and nutrient transportation to the above-ground planting section, thereby affecting the growth of plant biomass and overall plants. Leaves are exposed to lead with high concentrations which cause build up on the leaves so that leaf development is inhibited such as changes in leaf structure, cell wall damage and epidermal cell shrinkage [18]. Lead causes damage to chloroplasts, inhibits leaf growth, inhibits photosynthesis and damages cell membranes [19] and therefore it decreases production biomass.

Heavy metal content differs in plant tissue, depending on the concentration of lead exposure and plant species. In this research, lead content in the root tissue was higher than stem and leaf tissue Codiaeum variegatum plant. The lead content is more in the roots than the stem and leaf due to the positive charge on the metal, allowing its absorption into the negatively charged root cell wall. After the lead penetrates into the root system, lead can accumulate there or may be transferred to the air plants parts. For most plant species, most of the lead that is absorbed accumulates in the roots, and only a small portion is translocation to parts of the air plant, as has been reported in sun flower [20], Allium sativum [21]. In another study, Celosia cristata pyramidalis accumulate lead 3 times more in roots than shoots [22].

Bioaccumulation is the ability of plants to accumulate lead, in this study lead bioaccumulation in stems + leaves is relatively higher than roots. Bioaccumulation factor (BAF) in Codiaeum variegatum decreases with increasing lead concentration. TF value to determine the ability of plants to translate lead from roots to shoots. In this study BAF values less than 1 and TF value more than 1. In general, heavy metals move through the root tissue then translocation occurs to other parts and localization or accumulation of metals in certain tissues. TF value > 1, indicates metal translocation from root to stem or leaf, while TF value <1. showing more metal accumulated in the root tissue. Generally, plants have tolerance and can accumulate heavy metals related to the purpose of phytostabilization and...
phytoextraction. Plants with more than one BAF and TF (TF and BAF> 1) have the potential to be used in phytoextraction. Other than that, plants with BAF greater than one and a TF less than one have the potential for phytostabilization. The phytoextraction process is the existence of heavy metal translocation to the upper organs while the phytostabilization process is the ability of plants to reduce metal translocation from the root to the upper organs. TF value is influenced by antagonistic and synergistic properties metals, which will affect metal absorption and distribution in plants [23].

The ability of plants to grow at heavy metal concentrations compared to controls was measured from the value of the metal tolerance index (MTI) [24,25]. Plants that have a high tolerance can be used in contaminated areas. Plant classification based on metal tolerance index (MTI) 0 ≤ 25 is very sensitive, 25 ≤ 50 sensitive, 50 ≤ 75 moderate, 75 ≤ 100 tolerant and ≥ 100 very tolerant. The value of MTI decreases with increasing concentration which indicates a decrease in growth and adaptation. This is considered when Pb content in the media. Based on MTI values, *Cordiaevaum variegatum* is identified as a plant that can tolerate lead. Plants that are adaptive when absorbing metals form reductase enzymes in the roots, where the enzymes function to reduce metals which then metals are transported in the root membrane [26].

**Conclusion**

The results of this study indicate that the decrease in plant biomass was not significantly different and *Cordiaevaum variegatum* can accumulate and tolerance to lead. The capability of plants to accumulated and tolerance of metals makes plant species an excellent candidate in remediating lead-contaminated soils.

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