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The absorption and accumulation of lead in *dracaena sanderiana* plant

*by **Hồ Bích Liên** (Thu Dau Mot University)*

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Corresponding author: lienhb@tdmu.edu.vn
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ABSTRACT

Heavy metals are the most dangerous substances in the environment, have caused deleterious effect not only to the environment but also to the public's health. Different studies have demonstrated that plants have a high removal capacity for lead ions from pollution sources. However, these plant species were rather limited. Thus, the project aimed to find out plant species that represent its lead removal ability to reduce environmental pollution. The experiment was carried out factorially as a randomized complete design in hydroponic systems with four treatments (0, 100, 200, and 300mg/l of Pb) and three replications. The results indicated that the growth of the Dracaena sanderiana plant is well in Pb concentration of 100mg/l, with less growth while the increasing lead concentration of 200 mg/l and 300 mg/l. The amount of lead in the water of three treatments 100mg/l, 200mg/l, and 300mg/l after 30 days of the experiment decreased by 91.5%, 86.8%, and 86.4%, respectively. It was found that Dracaena sanderiana exhibited high lead treatment efficiency in the water. Moreover, results showed that the accumulation of lead in the roots of Dracaena sanderiana is quite large with treatments of 100mg/l, 200mg/l, and 300mg/l lead concentrations were 5073.8mg/kg, 5134.0mg/kg, 7054.0mg/kg, respectively. In contrast, the ability to lead accumulation in plant leaves and stems is lower.

Keywords: *dracaena sanderiana, heavy metals, lead*

1. Introduction

Today, the continuous development of science and technology has brought many economic benefits to humans; however, this also makes the environment more seriously polluted (Nguyen Thi Ha, 2010). In Vietnam, the pollution of heavy metals, especially lead (Pb) pollution is becoming increasingly popular due to the massive development of human, agricultural, and industrial activities (Nguyen Duy Bao, 2012). Heavy metals are the most dangerous substances in the environment and have caused deleterious effects not only on the environment but also on the public's health (Karen et al., 2013). Thus, the search for lead treatment methods has to be taken as a priority in many countries.

Different techniques of lead decontamination are available, the most common is physical chemistry. They can process the contaminated soil in-situ or ex-situ by using techniques involving chemicals, as chelating, and physical methods such as pumping or heating. Recently, techniques based on the use of plants have been developed for soil and water remediation. These techniques of phytoremediation are less invasive and less expensive than the physicochemical techniques (USEPA, 2000), but it involves the identification of plant species with particular capabilities. To be used in lead decontamination, the plants should tolerate the presence of high concentrations. In addition, they must be capable of accumulating the contaminant in their roots or in their shoots. However, these plant species were rather limited. finding out plant species that represent lead removal's ability to reduce environmental pollution is one of the most interesting subjects for scientists.

Recently, the research of Nguyen Duy Duy (2011) indicated a plant's ability to absorb heavy metals such as copper, nickel, and chrome for the process of phytoremediation, namely, *Dracaena sanderiana* plant. Nguyen Thi Ha's research (2010) has shown that *Dracaena sanderiana* has the ability to grow well in wastewater or garbage. However, the accumulation and absorption of lead *by Dracaena sanderiana* have not been researched yet.

Consequently, this work has been conducted to study various aspects of responses that Dracaena sanderiana in the presence of lead and find plant species that represent its lead removal ability to reduce environmental pollution.

2. Materials and methods

Plant samples: 108 *Dracaena sanderiana* plants were purchased from a breeding center in Binh Duong province, Vietnam. The plant was bred in distilled water until its root achieved 4-5cm.

Artificial lead solution: In this study, the adsorption and accumulation of lead (Pb) by *Dracaena sanderiana* was investigated under artificial hydroponic conditions including the composition of distilled water and Pb $(NO_3)_2$ at a pH level of 5.0.

***Experiment**:* The experiment was done single-factor in the form of a completely randomized design, constituted of four treatments with four Pb $(NO_3)_2$ levels: 0 mg/l; 100 mg/l; 200 mg/l, and 300 mg/l distilled water and three replicates. The experiment was carried out in the research greenhouse, of resources and environmental faculty, at Thu Dau Mot University, Binh Duong Province, Vietnam in 2015. The average relative humidity of the greenhouse was 60% and the dark and light average temperatures were 28 °C and 34°C respectively. After root getting, nine *Dracaena sanderiana* plants were grown hydroponically in each treatment.

***Plant harvesting and heavy metal analysis**:* The plant samples were harvested at three time periods (10, 20, and 30 days). The initial and every 10 days of treatment lead concentration of the plant and artificial lead solution were determined using Flameless Atomic Absorption Spectrophotometer (AA-7000, Shimadzu, France). For each harvest period, 1g of leaves or stem or root from one *Dracaena sanderiana* plant of treatment was collected. The plant samples were oven dried at 60^oC for 24 hours. The samples were crushed into a fine powder and sieved through a 1.5 mm sieve. To 1.0 g of the samples per group, 10mL of a mixed solution of nitric acid, hydrochloric acid, and hydrogen peroxide ($10HNO_3$: $1HClO_4$: $1H_2O_2$) was used to macerate the sample for 24 hours. The samples were digested for 4 hours at 100^oC. Samples were then diluted to 50mL with $HNO_3$5% and analyzed by FAAS (Perkin-Elmer,1996).

Flameless atomic absorption spectroscopy: The lead content of the samples was analyzed using a flameless atomic absorption spectrophotometer (AA-7000, Shimadzu, Japan).

Preprocessing to analysis, the spectrophotometer was calibrated with standard lead solutions (0.5, 1, 2, 5, 8, and 10mg/l for the plant and water samples) using distilled water as blank. The standard solutions and distilled water were provided by the Environmental Laboratory of Thu Dau Mot University. Lead concentration levels were expressed in mg/l units.

Analysis of data: Data were analyzed by Microsoft Excel version 2010 and MSTAT-C.

3. Results and discussion

Effects of lead (Pb) uptake on the growth and development of Dracaena sanderiana plant

The results of stem height growth are represented in Figure 1. The results showed that *Dracaena sanderiana* was not only able to live in three different Pb concentrations of 100mg/l, 200mg/l, and 300mg/l but also increase growth during the periods of study time. After 30 days of lead exposure, *Dracaena sanderiana* plants of various concentrations did not show reduced growth compared to the control plants without any symptoms of metal toxicity.

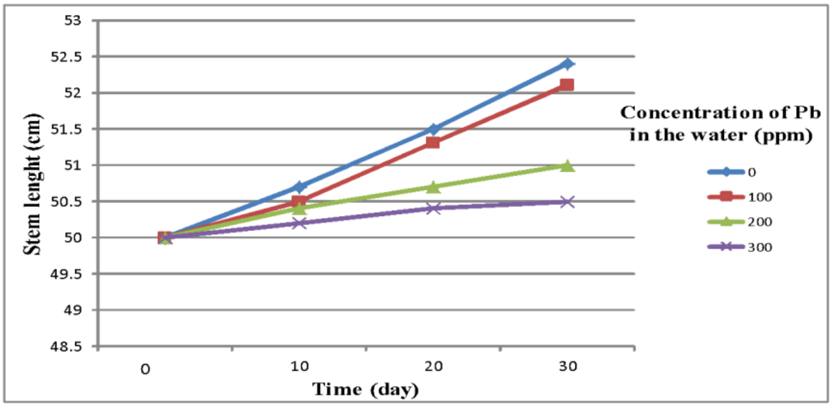

Figure 1. The height growth of *Dracaena sanderiana* plant in treatments following timeline

Results revealed that in three Pb levels, the highest increase (up to 4.2%, 57.1%, and 15.0%) in stem length, root length, and leaf number, respectively of *Dracaena sanderiana* plant was observed in treatment 100mg/l as compared to initial (less than control treatment). The increase in stem length, root length, and leaf number is decreased gradually when Pb concentration increased gradually (table 1).

TABLE 1. Effects of Pb uptake on stem and root growth, and the number of leaves of *Dracaena sanderiana* plant under experimental conditions

Treatments	**Stem length (cm)**		**Root length (cm)**		**The number of leaves (leaf)/a tree**	
	Initial	30 days	Initial	30 days	Initial	30 days
0mg/l	50.0^{a}	52.4^{a}	7.0^{a}	13.0^{a}	8.0^{a}	10.0^{a}
100mg/l	50.0^{a}	52.1^{b}	7.0^{a}	11.0^{b}	8.0^{a}	10.0^{a}
200mg/l	50.0^{a}	51.0^{c}	7.0^{a}	8.0^{c}	8.0^{a}	9.0^{b}
300mg/l	50.0^{a}	50.5^{d}	7.0^{a}	7.0^{d}	8.0^{a}	9.0^{b}

At the same column, means sharing similar letter do not differ significantly at p>0.05

TABLE 2. Effects of Pb uptake on fresh weights of *Dracaena sanderiana* plant under experimental conditions

Treatments	**fresh weight (g)**		**The increase of fresh weight after 30 days (g/tree)**
	Initial	**30 days of the experiment**	
0mg/l	42.3 ± 1.3	58.0 ± 3.0	15.7^{a}
100mg/l	47.4 ± 3.5	67.1 ± 1.9	19.7^{a}
200mg/l	49.6 ± 3.2	59.7 ± 4.7	10.1^{b}
300mg/l	52.0 ± 2.5	59.4 ± 2.3	7.4^{b}

At the same column, means sharing similar letter do not differ significantly at p>0.05

Results regarding the fresh weight of *Dracaena sanderiana* plant are presented in table 2. Results showed that the fresh weight of *Dracaena sanderiana* in four treatments 0mg/l, 100mg/l, 200mg/l, and 300mg/l increased as compared to initially, up to 37.1%, 41.6%, 20.4%, and 14.2%, respectively (table 2). The highest increase in fresh weight of

Dracaena sanderiana plant was recorded up to 41.6% in response to 100mg/l lead (higher than the control). While rest of the treatments also showed a significant increase in fresh weight. However, the increase in fresh weight is also decrescent when lead concentration is increasing.

From our results, it is also concluded that with increasing lead concentrations in water, stem, root, and leaf growth and fresh weight of *Dracaena sanderiana* plant decreased gradually. Our results are in line with R. Usha et al., (2011) who noted that sunflower (*Helianthus annuus* L.) showed symptoms of lead toxicity at increasing gradually concentrations. It was also proved that *Dracaena sanderiana* plant could grow and develop well in lead-contaminated water up to 100mg/l. Our results showed *Dracaena sanderiana* plant exhibits a withstanding ability of lead higher than some plants such as sunflower (*Helianthus annuus* L.) (15mg/l) R. Usha et al. (2011),

Absorption and accumulation of lead in Dracaena sanderiana plant

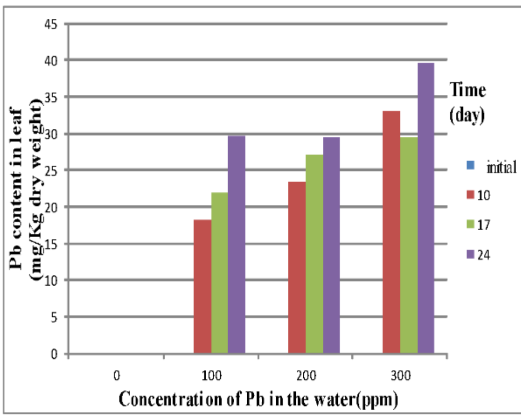

Figure 2. Accumulation of Pb content in *Dracaena sanderiana* leaf according to timeline

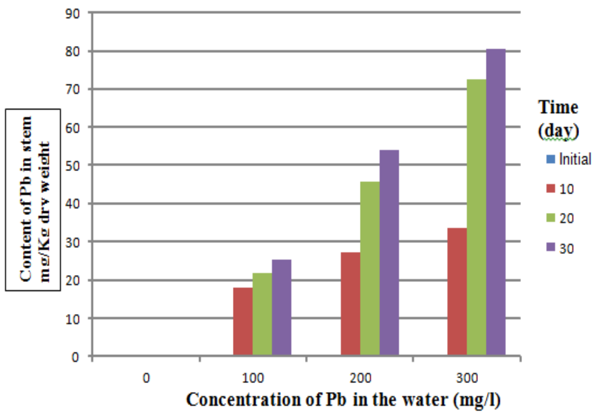

Figure 3. Accumulation of Pb content in *Dracaena sanderiana* stem according to timeline

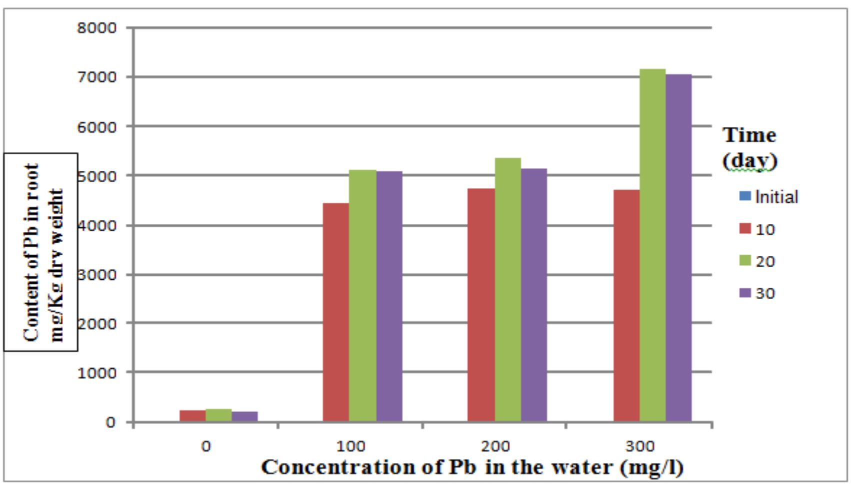

Figure 4. Accumulation of Pb content in *Dracaena sanderiana* root according to timeline

Results about Pb contents which accumulated in the parts of *Dracaena sanderiana plant* is presented in figure 2, figure 3, and figure 4. Accumulated Pb content in the parts of the *Dracaena sanderiana* plant increased gradually according to time periods.

Uptake of Pb in leaf was recorded up to 29.7, 29.6, and 39.6 mg/kg in response to 100mg/l, 200mg/l, and 300mg/l, respectively. Tran Phap's research (2012) reported that accumulated Pb content in *Phragmites australis*'s leaf up to 6 mg/kg in dry weight. It is concluded that accumulated lead content in the leaf of *Dracaena sanderiana* is higher than in *Phragmites australis*'s leaf.

TABLE 3. Concentration and the total accumulation of lead in *Dracaena sanderiana* leaf under hydroponic conditions

Pb concentration in water (mg/l)	**Pb contents in *Dracaena sanderiana* leaf (mg/kg dry weight)**			
	initial	**10 days**	**20 days**	**30 days**
0	0	0	0	0
100	0	18.3^{a}	22.0^{a}	29.7^{a}
200	0	23.4^{b}	27.1^{a}	29.6^{a}
300	0	33.0^{b}	25.0^{a}	39.6^{a}

At the same column, means sharing similar letter do not differ significantly at p>0.05

Results regarding lead contents in stem (table 4) revealed that accumulated lead content in the stem of *Dracaena sanderiana* plant increased gradually according to time in three Pb levels in the water. In treatments 100mg/l, 200mg/l, and 300mg/l, the contents of Pb in the stem were recorded in turn as not detectable, 17.8, 21.7, and 25.3mg/kg dry weight; not detectable, 27.0, 45.1 and 54.1mg/kg dry weight; and not detectable, 33.4, 72.8 and 80.2mg/kg dry weight, respectively. In comparison with Reeves and Books' research result (1983) recorded that *Thalaspi rotundifolium* plant accumulated content of lead in the stem up to 82000mg/kg dry weight, the content of lead in the stem of *Dracaena sanderiana* plant accumulated smaller than very much. In comparison with the absorption and accumulation ability of Vetiveria *zizanioides* L. *Dracaena sanderiana* plant exhibited ability higher. It was shown by Vo Van Minh's research (2009) that *Vetiveria zizanioides* L. accumulated 38.231mg/kg dry weight of lead in the stem at an experimental lead level 300mg/l.

TABLE 4. Concentration and total accumulation of lead in *Dracaena sanderiana* stem under hydroponic conditions

Pb concentration in water (mg/l)	**Pb contents in *Dracaena sanderiana* leaf (mg/kg dry weight)**			
	initial	**10 days**	**20 days**	**30 days**
0	0	0	0	0
100	0	17.8^{a}	21.7^{a}	25.3^{b}
200	0	27.0^{a}	45.8^{a}	54.1^{ab}
300	0	33.4^{a}	72.8^{a}	80.2^{a}

At the same column, means sharing similar letter do not differ significantly at p>0.05

Data regarding lead contents in the root (table 5) showed that highest uptake of lead contents in root was observed in 300mg/l lead (up to 7054mg/kg dry weight) after 30 days of the experiment and smallest in 100mg/l lead (5073.8mg/kg dry weight). However, in the case of lead uptake, the root portion showed results different from the stem and leaf parts of *Dracaena sanderiana* plant. Lead accumulation in the root increased from 0 to 20 days of the experiment but it decreased from 20 to 30 days. It was noted that higher accumulation of lead content in *Dracaena sanderiana* plant compared to some aquatic plants such as the root of *Phragmites australis* plant (2430mg/kg dry weight), *Abutilon indicum* plant (4090mg/kg dry weight) and *Typha orientalis* plant (4850mg/kg dry weight) (Tran Phap, 2012)

TABLE 5. Concentration and the total accumulation of lead in *Dracaena sanderiana* root under hydroponic conditions

Pb concentration in water (mg/l)	**Pb contents in *Dracaena sanderiana* leaf (mg/kg dry weight)**			
	initial	**10 days**	**20 days**	**30 days**
0	0	0	0	0
100	0	4433.7^{b}	5115.9^{b}	5073.8^{b}
200	0	4721.2^{a}	5349.8$^{\mathbf{b}}$	5134.0^{b}
300	0	4703.8^{a}	7174.6^{a}	7054.0^{a}

At the same column, means sharing similar letter do not differ significantly at p>0.05

The ratio of Pb content in stem and leaf to lead content in root in table 6 was low and not different in statistical between treatments. *Dracaena sanderiana* plant absorbed and accumulated most of the lead content in the root. After 30 days of the experiment, the ratio of lead content in stem and leaf to lead content in root in three treatments with lead levels 100mg/l, 200mg/l, and 300mg/l were 1.1%, 1.68%, and 1.69%, respectively. It is concluded that *Dracaena sanderiana* plant can eliminate lead from the water environment by the mechanism of rhizofiltration. In addition, the ratio of lead content in the stem and leaf to lead content in the root increased according to time. It can be explained that *Dracaena sanderiana* plant is able to use the mechanism of phytoextraction to extract lead contaminants from water and transport it to stem and leaf parts.

TABLE 6. The ratio of Pb content in stem and leaf to lead content in the root (%)

Lead concentration in water (mg/l)	**The ratio of lead content in stem and leaf to lead content in the root (%)**		
	10 days	**20 days**	**30 days**
0	0	0	0
100	0.82^{a}	0.83^{a}	1.10^{a}
200	1.07^{a}	1.35^{a}	1.68^{a}
300	1.42^{a}	1.36^{a}	1.69^{a}

At the same column, means sharing similar letter do not differ significantly at p>0.05

The results about a change of Pb concentration in water

The results from table 7 showed that lead concentration in water decreased significantly compared with initial day of the experiment. Lead concentration in water decreased higher in the time period from 0 to 20 days than from 20 to 30 days of the experiment. After 30 days of the experiment, lead concentration in water decreased by 95.1%, 86.8%, and 86.4% as results of 100 mg/l, 200 mg/l, and 300 mg/l, respectively. It exhibited that *Dracaena sanderiana* plant treats effectively lead at all lead levels in this study.

TABLE 7. Change results of Pb concentration in water

Initial concentration of Pb in water (mg/l)	Concentration of Pb n water after 30 days of the experiment (mg/l)			
	1 day	**10 days**	**20 days**	**30 days**
0	0	0	0	0
100	100.0^{a}	31.8^{b}	11.1^{c}	4.9^{c}
200	200.0^{a}	56.4^{b}	27.9^{c}	26.5^{c}
300	300.0^{a}	76.3^{b}	41.4^{c}	40.7^{c}

At the same row, means sharing similar letter do not differ significantly at $p>0.05$

4. Conclusion

Based on the results presented, it can be concluded that *Dracaena sanderiana* plants still grow well in lead-contaminated treatments (up to 300 mg/l). With the increase in the levels of lead in the water, the absorption of lead in aerial parts increased. Lead accumulated higher in the root than in the stem and leaf. *Dracaena sanderiana* plant treated effectively lead in the water with an average removal efficiency above 85%. Rhizofiltration and phytoextraction are able to be the main mechanisms of *Dracaena sanderiana* plant to uptake and remove Pb from the contaminated water.

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