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ORIGINAL ARTICLE

Kinetic Equations for Aquatic Plants' Lead Absorption from Industrial Sewage Sludge in Khuzestan

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ABSTRACT
Aquatic plants can absorb nutrients and heavy metals from soil and sewage sludge. In this study, the capability of three aquatic plant species, Typha latifolia ‹Phragmites australis, has been investigated in respect of lead absorption from sewage sludge in a hot and dry climate of Dezful. Each of the two plant species was cultured in systems; also some systems, without planet, were considered as a control, and it was conducted in a completely randomized design and the lead uptake of plant species in these treatments has been studied. The test included 6 pounds of sewage sludge, and 3 ponds without plant as a control group. The results showed that the lead accumulation in underground organs of both plant species was higher than shoots. Lead accumulation in the tissues of plant species of T. latifolia was more than that in the tissues of other species. At the end, Kinetics equations of absorption were extracted by Curve expert, 2007. The general form of absorption equations was fitted to exponential equation, these absorption equations are: $y = ae^{b/t}$ *and* $y = (1-e^{-bt})$*. In these equations, Y is the rate of heavy metal accumulation, t is time, a and b coefficients are regression coefficients. The results represent the superiority of T. latifolia over the other plant species under study.*
Key words: *Lead, Typha latifolia, Phragmites australis, sewage sludge*

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INTRODUCTION

The use of sewage sludge has always been considered by researchers and experts in agriculture and environmental section as a providing source of cheap nutrients in farmlands. By considering the increasing population growth and thus increasing sewage, and consequently increasing the sewage sludge, the agricultural use is one of the suitable and environmentally sound ways to prevent its accumulation. However, due to the high concentration of heavy metals in the sewage sludge combination, its direct consumption will cause some problems. Accumulation of heavy metals such as nickel, cadmium, lead and other toxic substances in the soil by using sewage sludge will cause their entrance into the food chain through the plant uptake and make toxicity. Artificial canebrake systems are those that have been used in many parts of the world with low cost and simple technology to refine different types of sewage. In these systems, the heavy metals existing in the sewage are removed by absorbing through aquatic plants, chemical combination, ion exchange, adsorption by soil, and other inorganic materials [2]. The results of a survey conducted by Vymazal [1] in Czech Republic, to determine the removal efficiency of heavy metals from an industrial sewage with artificial horizontal pond systems showed that this system could refine a lot of heavy metals such as copper (Cu), Chromium (Cr). *P. australis* and *Phalaris arundinacea* were plants examined in this study. The sampling of plant organs shows that the most decrease in Cu and Cr concentration has been respectively in plants' roots, rhizomes, stems and leaves. Manios *et al* [3] studied the effect of input concentration of heavy metals existing in sewage sludge on the uptake of these metals through aerial and underground organs of aquatic plant specie, *T. latifolia*. Heavy metals investigated in this study were Cadmium, Copper, Zinc, Nickel and Lead; the culture mediums were irrigated with water contaminated with above mentioned metals once every two weeks, and after 10 weeks sampling of plants' organs was done. The result showed that this plant specie has a high ability in absorbing metal; and the accumulation of these metals in aerial organs was higher than the underground organs. Therefore, the study of effective and environmental friendly methods for heavy metal removal from sediments and sludge is very important in order to minimize prospective health risk during application. Some aquatic plants can remove nutrients and heavy metals from media such as sediments that many studies are focused on accumulation of heavy metal by aquatic plants [4, 5]. Many species of plants have been successful in absorbing heavy metals such as lead, cadmium, chromium, arsenic, and nickel from soils. Some metals such as Cd, with unknown biological function can also be accumulated. From the aquatic plants, *T. latifolia* and *P. australis* are common wetland plant that grow widely in tropic and warm regions [6]. Also, removal and accumulation of cadmium and lead by *T.latifolia* exposed to single and mixed metal solutions were studied. Results confirmed the internalization of Cd and Pb in *T. latifolia* through scanning electron microscopy [7]. Concentrations of Cu, Zn, Pb, Cr, Cd, Fe, and Ni have been estimated in soils and mesophytic and aquatic plants grown in and around an industrial area of Bangladesh [8].

MATERIALS AND METHODS

Cultivation experiments in artificial canebrake systems were done in the summer of 2012 for 90 days in June, July and August. To conduct the second part of the experiments, six ponds with 5.0 m width, 6 m length and 8.0 m depth were established in a farmland of Islamic Azad University of Dezful. The bottom and the body of the ponds were insulated by three thick plastic layers. As previously mentioned, the young samples of plant species under study were moved to the laboratory immediately after collecting from the fringe of the marshy areas, and after light washing were cultivated in the system. Each of the two plant species was cultivated three times in systems; some systems without plant were considered as a control group and were conducted in a completely randomized design. Within each pond, there was 200 kg dried sewage sludge provided from the filtration plant of Ahvaz and its lead concentration was 480 mg in one kg of sludge. Two intended plant species were cultivated with a density of 50 plants per square meter. Given that during the pot experiment, two plant species of *T. latifolia* and *P. australis* had good absorption ability, they were used in the second part of the experiment. Then by considering the previous calculation of the ratio of dried sludge to water (ratio: 1:4) in respect of plants' tolerance to the sludge concentration and its salinity, 800 liters of water were added to each pond. Water height in the ponds was measured by an index after reaching to the volume to compensate the lost water, in the case of daily evaporation. Due to the hot weather, especially in July and temperature of 53 ° C on some days in Khuzestan, plants' need for the water was very high and to keep the wetland conditions, heavy irrigation was done every 2 days.

Harvesting plant samples

The total retention time for the plants in the ponds was considered 90 days and every 15 days, one complete plant was selected randomly, exited from the pond very carefully by shovel without causing any damage, and moved to the laboratory. After rinsing in the laboratory, the plants' samples were separated into the above ground organs (stem and leaves) and the below ground organs (roots and rhizomes); then weighed and dried at a temperature of 65 °C for 48 h; the dried plants' samples were weighted and after grinding, they were passed from a 75.0 mm sieve. On the last day of the experiment, the number of plants of each system in one square meter was counted, and according to the average weight of the harvested plant's organ the experiment of the weight of plant biomass was conducted on the 90^{th} day to calculate the percentage of the heavy metal removal per square meter of a system.

Analysis of plant's samples

After a light rinsing with cleaner liquid, plants' samples were separated to aerial and underground organs. After weighting plant's samples, they were dried at 65 ° C for 48 hours; then these dried plant samples were weighted, milled and passed from a 75.0 mm sieve. Then 2 g of plant sample was poured in a balloon, and 4 ml Perchloric *acid*, 2 ml Sulfuric acid, and 20 ml concentrated Nitric acid were added and was gently heated. Then the concentration of nutrient elements and heavy metals in the extracts was measured by atomic absorption, the model of Perkin Elmer A Analyst 700.

Data Analysis

Two plant species were cultivated there times in plant cultivation systems including sewage sludge and conducted in a completely randomized design. EXCEL software, 2007 version, was used for drawing graphs. SPSS software, version 13, was used for statistical analysis of phase one and two of experiments, and the comparison of means was performed by following Duncan's test. Curve expert, version 2007, was used for drawing the heavy metal's absorption curves and exponential regression formulas. At the end, the results of this study were compared, discussed and interpreted with the results of similar studies in the world.

RESULTS AND DISCUSSION

The concentration rate in tissues of aerial and underground organs of plant species of *T. latifolia* was higher than other species. Generally, the lead concentration of underground organs in the two plant species was higher than other their aerial organs. The low concentration in aerial organs indicates lack of lead transfer from below ground organs to above ground organs. According to the slope of the curves, the fastest absorption rate in plant's organs has been in the middle decades of growing period (IV & V). The highest concentration in the below ground organs of *T. latifolia* has been 6.10 mg per kg; and the lowest concentration has been 4.3 mg per kg in above ground organs(fig. 1 and 2) Various species of cultivated aquatic plants in the artificial canebrake system have the ability to absorb existing nutrients in urban, industrial and agricultural sewage. Since the form of absorption curves of various pollutants of different aquatic plant species is usually exponential, the Curve expert software was used in this study. And after entering data about time (from the beginning of the cultivation to the end of the understudy period in terms of day) and data about lead absorption rate in below ground and above ground organs of each plant species in the software, the exponential regression curves for each plant were drawn. The general form of these equations is:

$$y = a(1 - e^{-bt}) \quad (1)$$

$$y = ae^{(b/t)} \quad (2)$$

In these equations, t is the time in terms of day, and y represents the heavy metals' absorption rate in the plant's tissues. The coefficients of a and b are regression constant coefficient which are different for different plant species and organs. These coefficients have been calculated for each of the above models. These equations, indeed, are models which can contribute to predict the metal accumulation and aquatic plants' refinement capability in the same geographic conditions(table 1 and 2).

Table 1. Factors of Pb accumulation graphs in root tissues of aquatic plants

Aquatic Plant	Equation	a	b	s	r
T.latifolia	y=ae^(b/t)	237.8	-8.2	3	0.996
	y=a(1-e^-bt)	213.1	0.066	4.92	0.989
P.australis	y=ae^(b/t)	84.8	-11.7	1.18	0.996
	y=a(1-e^-bt)	74.2	0.049	1.26	0.996

Table 2. Factors of Pb accumulation graphs in leaf and shoot tissues of aquatic plants

Aquatic Plant	Equation	a	b	s	r
T.latifolia	y=ae^(b/t)	222.2	-26	5.25	0.994
	y=a(1-e^-bt)	213.9	0.018	3.76	0.997
P.australis	y=ae^(b/t)	116.8	-21.7	8.5	0.948
	y=a(1-e^-bt)	119.2	0.018	5.5	0.978

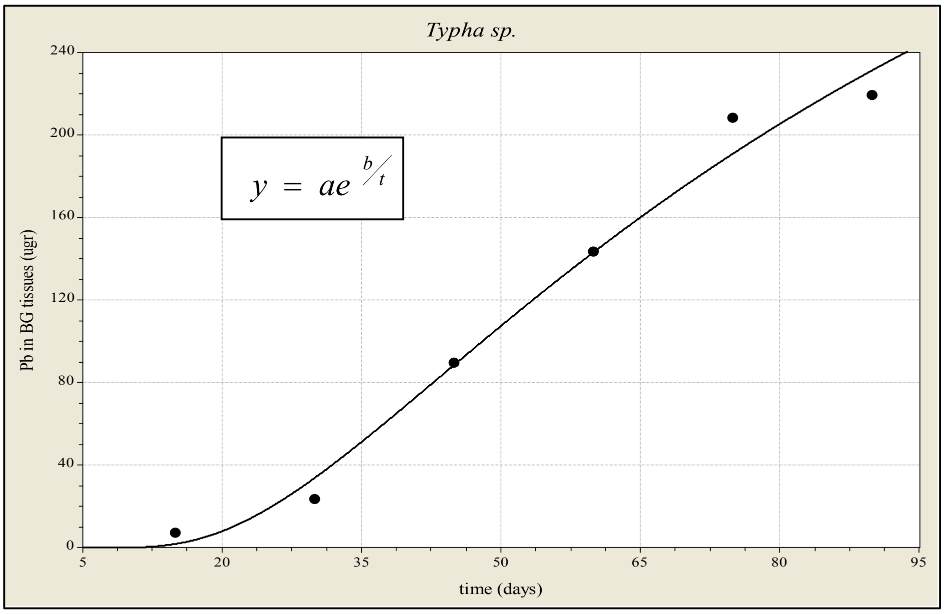

Fig 1. Pb accumulation in below ground tissues of *T.latifolia*

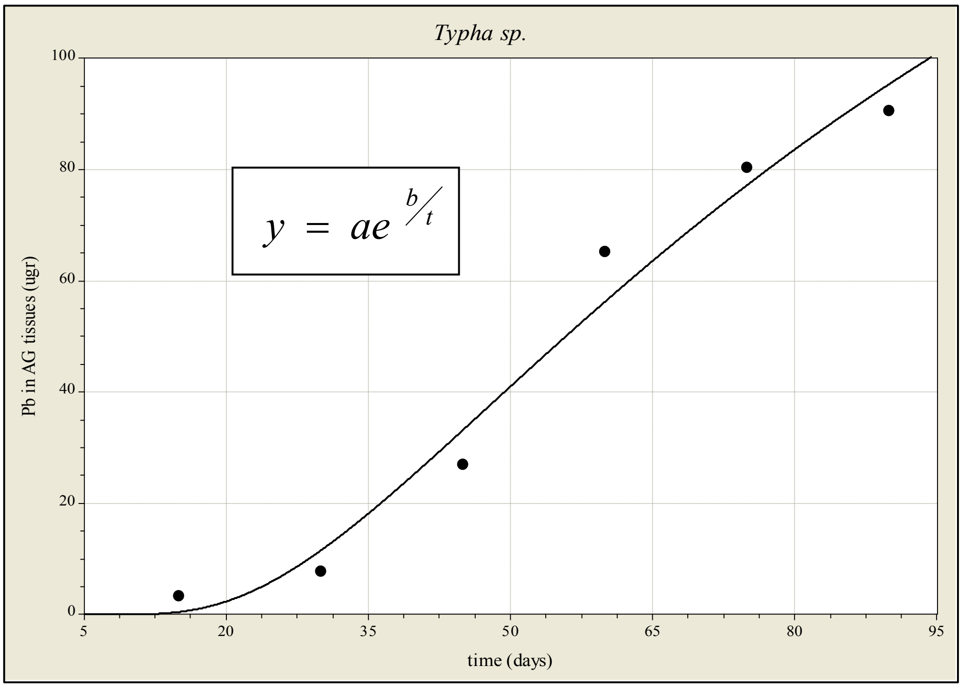

Fig 1. Pb accumulation in above ground tissues of *T.latifolia*

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