Phytoextraction of mercury (Hg) in soils contaminated by button batteries using Bamboo "*Bamnusoideae*"

Fitoextracción de mercurio (Hg) en suelos contaminados por pilas botón empleando Bambú "*Bamnusoideae*"

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Abstract

The pollution of the planet has generated a series of problems for the environment and human health, such as the case of soils contaminated by heavy metals from batteries that are improperly disposed of in domestic garbage and sanitary landfills; Button batteries (HgO) pollute the soil, since mercury is very persistent in the environment due to its biomagnification and its great capacity to accumulate in organisms causing diseases in humans at the skin level, respiratory tract, digestive system, etc. . this being a highly toxic metal worldwide. The accumulation of Hg in soils depends on physicochemical factors such as pH, redox potential, organic matter, and clay. The main objective of this research work is to implement mercury phytoextraction in soils contaminated by button cells, using "*Bamnusoideae*" Bamboo, a UV-Vis spectroscopic study was carried out to determine the desorption of Hg from the contaminated soil, images of the stem were obtained, leaves and roots of bamboo without contamination and contaminated with Hg with a VE-B6 microscope, rating: 85V to 265V 50/60 Hz, Halogen Lamp: 12V 30W, and the pH of the contaminated soil was measured.

Phytoextraction, Button batteries, Bamboo "*Bamnusoideae*"

Resumen

La contaminación del planeta ha generado una serie de problemas al medio ambiente y salud humana, tal es el caso de los suelos contaminados por metales pesados provenientes de las pilas descartadas inadecuadamente en la basura doméstica y rellenos sanitarios; las pilas botón (HgO) contaminan el suelo, ya que el mercurio, es muy persistente en el medio ambiente por su biomagnificación y su gran capacidad de acumularse en los organismos causando enfermedades en el ser humano a nivel cutáneo, vías respiratorias, aparato digestivo etc. siendo este un metal altamente tóxico a nivel mundial. La acumulación del Hg en los suelos depende de los factores fisicoquímicos como pH, potencial redox, materia orgánica y arcilla. Este trabajo de investigación tiene como objetivo principal implementar la fitoextracción de mercurio en suelos contaminados por pilas botón, empleando Bambú "*Bamnusoideae*", se realizó un estudio espectroscópico UV-Vis para determinar la desorción de Hg de la tierra contaminada, se obtuvieron imágenes del tallo, hojas y raíz del bambú sin contaminar y contaminado con Hg con un microscopio VE-B6, rating: 85V a to 265V 50/60 Hz, Halogen Lamp: 12V 30W, y se midió el pH de la tierra contaminada.

Fitoextracción, Pilas botón, Bambú "*Bamnusoideae*"

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Introduction

In recent decades, technological-industrial development has increased worldwide, offering a better quality of life to the population, however, energy expenditure, food production, etc., have caused environmental pollution (Bertheau, 2011). The contamination and degradation of natural resources, such as the soil, represents a great problem due to the serious impacts that are had on the environment and human health by heavy metals, which are highly toxic such is the case of mercury, although it has various uses to industrial level either for electricity, chemical mining, metallurgy and electrical.

In the electrical and electronic industry, it is used for its great ability to conduct electricity, the manufacture of button cells and/or mercury oxide (HgO) batteries, presents a long-term energy storage stability, for which they are used in portable devices (radios, toys, headphones, watches) (Weinberg, 2010). However, at the end of their useful life cycle, they are irrationally discarded to the common garbage dump and sanitary landfills were when they meet climatic factors (air, temperature, and water), their internal components begin to react, which are highly damaging to the environment. environment and human health, the accumulation of mercury in soils depends on the physical-chemical factors such as pH, Eh, organic matter, chlorine ions, and oxides of Fe and Mn (Lindsay 1979, Andersson 1979, Schuster 1991)

So scientists have been given the task in recent years of looking for viable and environmentally friendly alternatives to eliminate the mercury present in soils some of the in situ thermal desorption treatment techniques that physically separate pollutants from the soil by increase the temperature from 600 to 800 ° C obtaining gaseous mercury for purification and recovery (Kucharski et al., 2005); soil washing that involves the extraction of contaminants from the soil; Vitrification performs a heating of the pollutants until reaching the melting point and cools to have a solidified chemically inert glassy mass and immobilize the pollutants (Dermont, G., et al., 2008);

Solidification / Stabilization reduces the mobility of pollutants, encapsulating them in a matrix (solidification) is used when there are mercury concentrations lower than 260 mg/kg (Mahbub, 2017); Nanotechnology uses iron sulfate (FeS) particles with a nanoparticle size of 1-1nm, thus reducing the mobility, toxicity and bioavailability of pollutants (Carbrejo at. el., 2010); Phytoremediation which includes emerging techniques using different species of plants, in figure 1, a scheme of the three types of remediation that exist for mercury contamination is shown when using phytoremediation, which are: Phytostability where the roots of the plants immobilize and reduce the bioavailability of the pollutant through biochemical processes that take place in the roots or their surroundings (Dermont et. al., 2008);

Phytoextraction allows the pollutants to be captured by the roots and transported to the organs of the plant (stem and leaves), for their subsequent extraction and destruction or recycling, removing the metal from the soil (Wang, 2012);

Phytovolatization transfers pollutants from the soil to the atmosphere, using plants as intermediaries where metals are absorbed by the roots, transporting them through the xylem and subsequently released from cell tissues to the atmosphere, the most efficient of these processes is phytoextraction by remove the contaminant from the soil (Lázaro, 2008).

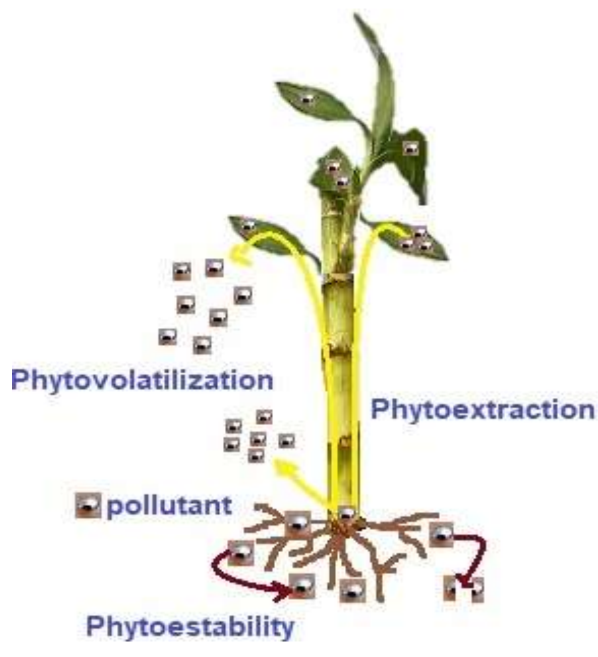

Figure 1 Scheme of the three processes of Phytoremediation of soils contaminated
Source: Own Elaboration

Methodology

Two "Bambusoideae" bamboo plants were planted, one was placed in a pot without Hg and the other in a pot contaminated with Hg from button cells, as shown in figure 2.

Figure 2 Image of the pots with bamboo, a) soil contaminated with Hg from button batteries, b) without Hg
Source: Own Elaboration

Subsequently, 1 gram of soil contaminated with Hg was collected for 65 days, samples of soil contaminated with Hg, and it was placed in a sterilized bottle containing 5 mL of water, these were perfectly closed and covered with aluminum.

UV-vis spectroscopic study

The spectroscopic studies were performed using a Perkin-Elmer Lambda 25 UV/Vis spectrometer, which has a tungsten and deuterium lamp, the spectra were obtained from 200 to 500 nm with a scanning speed of 240 nm/min

Bamboo images

Bamboo images were obtained using a VE-B6 microscope, rating: 85V to 265V 50/60 Hz, Halogen Lamp: 12V 30W, Delay-action Fuse: 1A.

Results

UV-Vis spectroscopic study and pH values

Table 1 shows the results obtained from the absorbance of Hg at the wavelength of 253.56 nm as a function of the time of the contaminated soil samples, as well as the obtained pH values.

Time/ days	Abs	[Hg]/ppm	pH± 0.05
1	0.54129	0.217	6.51
2	0.51321	0.206	6.36
4	0.49185	0.197	6.22
6	0.48630	0195	7.12
8	0.47872	0.192	6.25
10	0.46917	0.188	6.22
12	0.45597	0.183	6.22
14	0.45320	0.181	6.29
21	0.35991	0.144	6.36
28	0.30836	0.124	6.14
35	0.30617	0.123	6.22
49	0.28579	0.115	6.04
56	0.22570	0.091	6.00
65	0.21511	0.086	6.25

Table 1 The concentrations, and pH values of the samples taken from the contaminated substrate are shown
Source: Own Elaboration

As can be seen in table 1, it is clearly shown that there is a decrease in the concentration of Hg in the contaminated land as a function of time, with mercury concentrations higher than the permissible limits established by the Official Mexican Standard **NOM-147-SEMARNAT/SSA1-2004** regarding the concentration of soluble pollutants (CRs) that indicates that for mercury it is 0.020 ppm, which gives a clear indication of the serious contamination that is had in the soil by button batteries at the end of their life cycle of an inappropriate way.

In graph 1, the absorbances are shown as a function of time for the samples extracted from the substrate, where it is clearly observed that there is desorption of Hg as the days pass, it is important to clarify that these are the first studies carried out.

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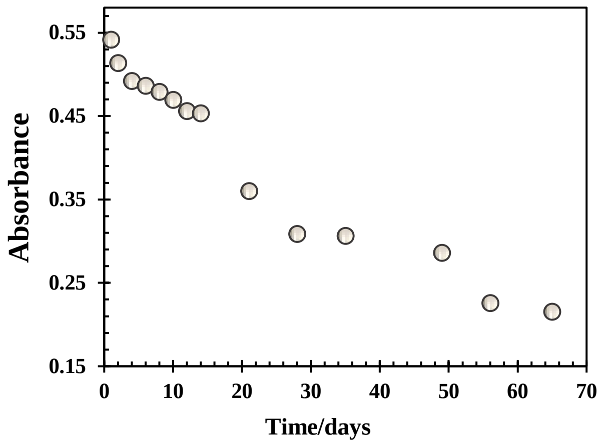


Graphic 1 Hg desorption graph in contaminated soil vs time in days
Source: Own Elaboration

The pH values obtained in this work indicate that there is a reduction of the Hg salts to Hg°, favorably increasing the loss of Hg by volatilization since, as reported in the literature by Frear at. the. when the pH rises from 5.3 to 6.4 there is less volatilization to the environment, according to the analyzes carried out so far it can be established that on earth the predominant species is mercury (II) hydroxide ($Hg(OH)_2$), which is a short-lived transitory intermediate in the formation of mercury oxide (HgO) in the alkaline aqueous medium, it has been determined that $Hg(OH)_2$ is a weak base and that it may be accompanied by $HgOH^+$ and Hg^{2+}, as shown in figure 3, distribution diagram of Hg (II) species as a function of pH in soils (Adriano, 1986).

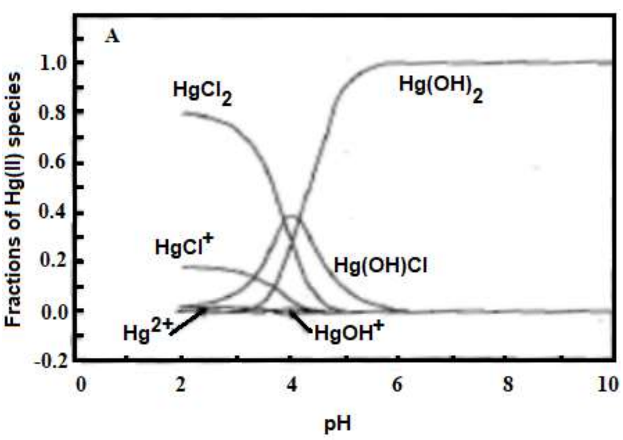
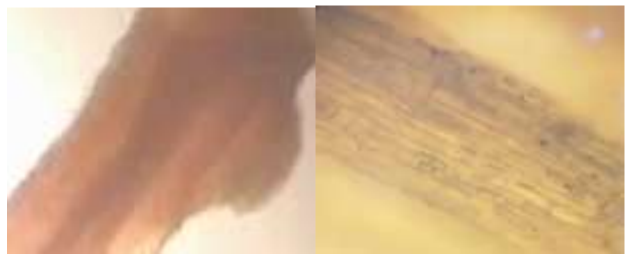


Figure 3 Hg (II) speciation as a function of pH (*Adriano, 1986*).

Leaf, stem and root images

Images of the leaves, stem and root of the bamboo were obtained without and with Hg, using a VE-B6 microscope, in figure 4.

The images obtained from the roots of the bamboo are shown, 4a without mercury and 4b with mercury as it can be Observe there is a great difference in the structure of the vascular cylinders found in the stela along with the xylem and phloem in the contaminated root, small clusters are observed changing the structure of the root, which gives evidence of the adhesion of Hg in it.



a **b**

Figure 4 Images of the bamboo root a) without Hg and b) with Hg
Source: Own Elaboration

In figure 5, the images of the stem are shown, 5 a) without Hg and 5 b) with Hg, as can be seen, there is a clear alteration in the structure of the metaxylem vessel and of the protoxylem vessel in the stem structure when absorbing the Hg.

a **b**

Figure 5, Images of the bamboo root a) without Hg and b) with Hg
Source: Own Elaboration

In figure 6, the images of the leaves are shown, 6 a) without Hg and 6 b) with Hg, in figure 5a no change is shown in the structure of the bamboo leaf, only small drops of water are distinguished, in figure 6b, it can be seen that there is actually an absorption of Hg in the structure of the sheath and trichomes in the cross-section, observing metallic clusters.

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a b

Figure 6 Images of bamboo leaves a) without Hg and b) with Hg
Source: Own Elaboration

In order to corroborate the presence of mercury in the stem, leaves, and root of the bamboo, a UV-vis spectroscopic study was carried out, for this, acid digestion was carried out on the samples to extract the amount of Hg contained, the spectrum It was the neighborhood in a wavelength of 200 to 500 nm, observing at 253.56 nm the absorbance of Hg in the contaminated samples, in the samples without mercury no absorbance was detected at that length, in table 2 the concentrations of Hg in the stem, leaves, and root of bamboo.

samples	Abs	[Hg]/ppm	pH± 0.05
Leaf	3.1033	$3.09\text{x}10^{-5}$	5.32
Stem	1.0706	$5.94\text{x}10^{-6}$	5.65
Root	1.2037	$6.68\text{x}10^{-6}$	5.45

Table 2 Hg concentrations, absorbance and pH value of leaves, stem, and root
Source: Own Elaboration

The data obtained show that in the stem there is a lower concentration of Hg than in the root and there is a higher concentration in the leaves, the Bamboo is capable of concentrating and precipitating the Hg of the soil in the biomass due to its high potential as a phytoremediator being This is a good candidate to capture metal ions through the roots and accumulate these in their stems and leaves in a friendly and economical way without altering the environment and human health, according to the literature the wavelength in UV- Vis at 253.65 nm there is the presence of inorganic Hg ° this is not susceptible to any of the main mechanisms of dry deposition and has very low solubility in water, elemental mercury is deposited through a series of chemical reactions in the drops of water of the clouds as expressed in the following equations.

$$\text{Hg}^{\circ}_{(\text{g})} \rightarrow \text{Hg}^{\circ}_{(\text{aq})} \quad (1)$$

$$\text{Hg}^{\circ}_{(\text{aq})} + O_3 \rightarrow Hg(II)_{(aq)} \quad (2)$$

$$\text{Hg(II)}_{(\text{aq})} + \text{polvo/evaporación} \rightarrow \text{Hg}_{(\text{II})(\text{p})} \quad (3)$$

$$\text{Hg}_{(\text{II})(\text{aq})} + \text{SO}_3^{2-} \rightarrow \text{Hg}^{\circ}_{(\text{a})} \quad (4)$$

This type of mechanism opens a possible deposition path for elemental mercury present in the atmosphere.

Acknowledgments

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Conclusions

The spectroscopic UV-Vis study allowed identifying that the bamboo “Bamnusoideae” is a good candidate to be used as a phytoremediator of soils contaminated with mercury from discarded button cells, obtaining Hg concentrations in the root of 6.68x10-6 ppm, in the stem 5.9x10-6 ppm and in the leaves 3.09x10-5 ppm and having an average desorption concentration of Hg in the soil of 14.07 ppm. The images obtained in the microscope give clear evidence of the presence of mercury in the root, stem and leaves by changing their morphological structure.

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