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Research Paper

Effects of different concentrations of mercury on accumulation of mercury by five plant species

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ABSTRACT

The paper studied the absorption of Hg by five common herb species selected, *Opuntia stricta*, *Aloe vera*, *Setcreasea purpurea*, *Chlorophytum comosum* and *Oxalis corniculata*, in solution with different levels of mercury. We compared the accumulation of roots and shoots of the plants selected in medium containing different concentrations of mercury. The study was to explore what extent of mercury the five plant species were suitable for absorbing and transferring. The mercury amount uptake by five herb species was tested by CVAAS. The results demonstrated that the effect of different concentrations of mercury on the accumulation condition of roots was greater than that of shoots. There was an ideal Hg concentration for transfer by each plant species. *Oxalis corniculata* was the most suitable for transferring Hg and was more suitable for repairing soils with Hg at concentrations of less than 500 μg/L.

1. Introduction

Heavy metals have become some of the most hazardous pollutants ever since the industrial revolution and some researchers recently have taken some methods to treat heavy metal pollution (Jiang et al., 2013; Lin et al., 2012; Wan et al., 2011). Mercury is an element which is non-essential to human life and is extremely harmful to the environment. Since the industrial revolution, substantial quantities of mercury have been released into the environment. For example, gold mining activities in many developing countries using gold amalgam technology lead to significant mercury pollution in nearby soils and water bodies, and a serious problem of mercury pollution also exists in developed countries (Li et al., 2015; Telmer and Veiga, 2009; Cordy et al., 2011; Drace et al., 2012; Krisnayanti et al., 2012). Currently mercury-containing waste is increasing in the world. According to some investigations, mercury-contaminated soils have caused a significant menace to water supply which in turn affects the quality of agricultural products (Horvat et al., 2003; Qiu et al., 2005). Organic mercury, e.g. Methyl mercury (MeHg) and dimethyl mercury (DMeHg), is a more toxic pollutant posing a significant menace to human and wildlife compared to inorganic mercury (NRC, 2000). What's more, Hg can be transported over long distances in the atmosphere (Engstrom and Swain, 1997; Munthe et al., 2007). Mercury is classified as a global pollutant by WHO and many country governments. Therefore, the mercury in soils damages soil and water functions directly and mercury pollutants, especially methyl mercury ultimately affects plants, animals and human health. Currently, the remediation of mercury-contaminated soils has become a very urgent task over the world.

Mercury pollution is a global environmental problem (Schroeder and Munthe, 1998; Boening, 2002). Many countries have invested substantial manpower and material resources to research the removal way of mercury in mercury-contaminated soils. Traditional repair methods include soil excavation, soil

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Fig. 1. Five plant species medium experiment.

cleaning, electrokinetic remediation, solidified and extraction through physical and physical chemical remediation technologies. These ways have a low efficiency coupled with high expenses and destroying soil microenvironment greatly. However, phytoremediation, a new in-situ remediation biotechnology using plants for removal of waste from contaminated soils, has obtained wide public acceptance gradually (Kraemer and Chardonnens, 2001). Compared to the traditional chemical, physical, engineering repair and other technical methods, phytoremediation is regarded as an efficient and cost-effective repair method with high public acceptance (Lambrechts et al., 2011; Pandey, 2012; Sinha et al., 2013).

For nearly 20 years, phytoremediation technology has been widely used for the repair of heavy metal contaminated soils. Many developed countries have carried out large-scale experiments, notably America and other countries use hyperaccumulators that have been found for phytoremediation of copper, plumbum, zinc, nickel, cadmium, gold and arsenic-contaminated soils (Andreazza et al., 2013; Huang et al., 1997; Anderson et al., 1998; Petkewich, 2004; Ma et al., 2001). The results have been positive. However, at present the hyperaccumulators for mercury haven't been found yet. Liu et al. studied some plant species in $HgCl_2$ solution with only a certain concentration for phytoremediation and found some meaningful results (Liu et al., 2014; Liu et al., 2015). But the Hg concentration is a consideration for the repair of heavy metal contaminated soils. The aim of the study is to explore what extent of mercury-contaminated soils the five plant species (*Opuntia stricta*, *Aloe vera*, *Setcreasea purpurea*, *Chlorophytum comosum* and *Oxalis corniculata*) were suitable for repairing. This would provide a basis to explore the use of plants to repair mercury-contaminated soils.

2. Materials and methods

2.1. Design plan

The test plants were divided into eight identical groups: No.1 was cultivated in a 100% Hoagland solution and No. 2 to No. 8 also in a 100% Hoagland but with 2, 10, 50, 100, 200, 500, and 800 $\mu g \cdot L^{-1}$ $HgCl_2$ solution, respectively. Conical flasks (500 mL) were used to contain 200 mL of fresh nutrient medium in each group. Cotton was stuffed to the top of conical flasks in order to prevent Hg evaporating from the nutrient solution in conical flasks. The plants were put in places sheltered from rain (Fig. 1).

The aim of this experiment was to explore what extent of mercury-contaminated soils the five plant species were suitable for phytoextraction. Group 1 plants were regarded as background plants. After 7 days, observations and tests for the plants were made.

2.2. Experiment

After 7 days, parts of roots and shoots of each group of test plants were cut off. They were cleaned with deionized water respectively. Subsequently, the samples were naturally dried to a constant weight. The samples were crushed and put into appropriate lengths respectively. Roots, stems and leaves of each group were put in three 150 mL conical flasks respectively mixed with a little distilled water and shaken with 10 mL nitric acid. The weight of roots, stems and leaves is all 0.5 g. They were then put into a bath with a constant temperature set at 60 °C for heating digestion for 10 min. Next, a 7-milliliter mixture of sulfuric acid and nitric acid (volume ratio 1:1) was added to each conical flask shaken well. This caused a violent reaction and after it stopped, 10-milliliter of distilled water and 10-milliliter potassium permanganate solution were added to every conical flask. Each conical flask with a small funnel into each bottle mouth was put on a low temperature heating plate, for 40 min, bringing the mixture to near boiling. In the decomposition process, a potassium permanganate solution was added to keep it excess if purple color faded. After 40 min, the conical flasks were static to cool. Before tested, a hydroxylamine hydrochloride solution was added to every conical flask shaken until the surplus potassium permanganate and hydrated manganese dioxide in the flask wall faded. The mercury amount in each part of the plants was tested by cold vapor atomic absorption spectrometry (CVAAS, AA-6300(P/N 206- 51800)).

3. Results and discussion

The results showed that the accumulation of Hg by roots and shoots of five plant species in solutions with different concentrations of mercury was different after 7 days. The effect of different concentrations of mercury on the accumulation of roots was greater than that of shoots of five plant species. The accumulation of Hg by roots and shoots increased with growing Hg concentrations. The accumulation of mercury by roots of *Opuntia stricta*, *Aloe vera*, *Setcreasea purpurea*, *Chlorophytum comosum* was much more than that of *Oxalis corniculata*. Because the root biomass of *Opuntia stricta*, *Aloe vera*, *Setcreasea purpurea* and *Chlorophytum comosum* was significantly higher than that of *Oxalis corniculata* after 7 days (Table 1). However, the accumulation of Hg by shoots of *Oxalis corniculata* was much more than that of other four plant species (Fig. 2).