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Biosorption of Pb (II) Ions from Aqueous Environment Using Low-Cost Biosorbents.

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ABSTRACT

Plant-based material plays a significant role in adsorption of heavy metals which are toxic to biospheres. In this study, selective biosorption of Pb (II) from aqueous solution by using two low cost biosorbents, such as, seeds of *Phyllanthus emblica* (amla) seeds and leaves of *Psidium gujava* (guava). This bioremediation technology was studied in the batch experimental systems. The lead ions adsorption efficiency was optimized under different conditions. Both biosorbents were used separately for biosorption of Pb (II). In case of amla seed powder, the percent biosorption of Pb (II) under the optimum conditions was 98 % with an effective dosage of 4.0 g/100 ml of biosorbent at optimum pH 4.0 for incubation time of 2 h which is better than guava leaf powder, where percent biosorption of Pb (II) under the optimum conditions was 89 % with same biosorbent dosage and same pH for same contact time. These results suggest that removal of the poisonous lead ions from solutions is possible using these low cost biosorbents.

Keywords: Biosorption, lead, biosorbents, *Phyllanthus emblica*, *Psidium gujava*.

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INTRODUCTION

Heavy metals pose a critical concern to human health and environmental issues due to their high occurrence as a contaminant, low solubility in biota and the classification of several heavy metals as carcinogenic and mutagenic [1,2]. The occurrence of toxic heavy metals in the soil is of geogenic or anthropogenic origin. They are important contaminants in the liquid wastes of a number of industries such as paint, dyes, glass operations, lead batteries, electroplating, mining and smelters [3]. Lead is one of the industrial pollutants; possibly enter to the ecosystem through soil, air and water. Inorganic lead causes disturbance in the central nervous system by changing the characteristics of the early organism [4,5]. According to WHO, the maximum permissible limit (MPL) of lead in drinking water is 0.1 mg/l [6]. Lead poisoning has many effects on the various systems in the human body and is capable of disrupting multiple biological processes. Some common side effects of lead poisoning are cognitive deficits, anemia, lower IQ scores, an increase in impulsivity, an inability to pay attention and an increase in crime and aggressive behavior. Lead also has effects on the reproductive system (low sperm counts and increases in stillbirth and miscarriage), kidneys, liver and gastrointestinal tract [7]. Therefore, to maintain the metal level the industrial waste undergoes with some conventional physicochemical methods, such as chemical oxidation and coagulation, filtration, electrochemical treatment, softening, flotation, and membrane separation. All these methods suffer from one or the other limitations [8], which are, for instance, complicated treatment process, high cost, generation of enormous quantity of toxic chemical sludge, energy consumption, and incomplete removal of waste [9,10].

Adsorption methods, which are based on physical and chemical phenomena that occur when the adsorbate molecules accumulate on the adsorbent surface, present some advantages over other methods, such as low investment cost, as well as possibility of using natural adsorbents which are environmentally safe. Biosorption results from electrostatic interactions and complex formation between metallic ions and functional group present in the cell surface. This approach which is more environmental friendly has been evaluated since the past few decades [11]. It has been considered as a potential alternative approach to remove pollutants from industrial effluents [12]. Furthermore, this technique has major advantages which include low cost, high efficiency, minimization of chemical or biological sludge and possible of regeneration of biosorbents [13-15]. Biosorption needs a biomass as an adsorbent which is naturally abundant, easily feasible and very selective.

Over the last 15 years there has been an increasing interest in developing a plant-based technology to remediate heavy metal-contaminated soils [16]. Biosorbents of plant origin are mainly agricultural by-products such as, maize cob and husk [17-20], sunflower stalk [21], medicago sativa (Alfalfa) [22], cassava waste [23], sphagnum peat moss [24].

This paper explores the potential of *Phyllanthus emblica* (amla) seeds and *Psidium gujava* (guava) leaves as novel adsorbents for removal of Pb (II) ions from wastewater since it has not been studied earlier. *Phylanthus emblica* is a deciduous and monoecious tree belonging to family Euphorbiaceae. Fruit is fleshy and drupa-ceous and the seeds are found within the hardened endocarp of the fruit known as stone [25]. *P. emblica* is famous for its medicinal values. In traditional medicine, it is known as one of "the best rejuvenating herbs" [26]. Psidium Guajava is a member of the *Myrtaceae* family. Guava is rich in tannins, phenols, flavanoids, essential oils, lectins, vitamins, fatty acids etc [27]. The leaves and bark of *Psidium guajava* tree have many medicinal uses [28]. The present study aimed to investigate the efficiency of amla seeds and guava leaves as biosorbents for the biosorption of Pb (II) from aqueous solution. Experiments were conducted to investigate the effects of pH, biosorbent dosage, adsorption time on the biosorption efficiency of Pb (II) by these biosorbents.

MATERIALS AND METHODS

Sample Collection and pretreatment

Two different plant samples were collected from Selaiyur (latitude: 12°93'00"N, longitude: 80°14'00"E), Chennai, India. *Phyllanthus emblica* (amla) seeds and *Psidium gujava* (guava) leaves were washed thoroughly with distilled water to remove dirt. The leaves were dried in a shed and seeds were sun-dried. The samples were dried until they became crisp. Then they compressed into a powder with the help of a manual grinder and the particles <1 mm sieved out. This size fraction was preserved in airtight containers separately for use as an adsorbent. Figure 1 (a, b) shows the biosorbents were used for further studies.

Figure 1: Low cost biosorbents a) seed powder of *Phyllanthus emblica* (amla), b) leaf powder of *Psidium gujava* (guava)

Preparation of Aqueous Solution

All chemicals were of analytical-reagent grade purchased from Merck, India. The experimental stock (1000 mg/l) solution was prepared from Lead Nitrate $Pb(NO_3)_2$ and further dilutions were prepared from this stock solution of Pb (II) with the use of distilled-deionized water. For the pH study, pH of the solutions was maintained by using 0.1N HCl/0.1N NaOH. Standard lab ware and glassware cleaned with HNO_3 and rinsed with double distilled water were used all over.

Analysis methodology

The concentration of $Pb(NO_3)_2$ in the aqueous solution is determined by observing absorbance with the help of UV-vis spectrophotometer (Shimadzu, UV-1800). The standardization was carried out by correlating the absorbance of aqueous solution samples with the known concentrations of $Pb(NO_3)_2$. A standardized graph plotted between concentrations of Pb (II) ions in solution with absorbance as obtained using UV-vis spectrophotometer.

Batch sorption studies

The biosorption studies were carried out in the batch mode for the measurement of adsorption capabilities. In the batch adsorption experiments, the effect of adsorbent on the adsorption of the heavy metal ion Pb (II) was investigated. 100 ml of the aqueous solution containing 20 mg/100 ml lead (II) was treated with 4 g of adsorbent in a 250 ml conical flask for 60 min by shaking on a reciprocating shaker at room temperature. The flasks were shaken at a constant rate of 180 rpm to ensure that equilibrium was reached. It was assumed that the applied shaking speed allows all the surface area to come in contact with heavy metals ions over the course of the experiments. The study was performed at a constant temperature of 37 °C to be representative of environmentally relevant condition. The separation of the adsorbents and solutions was carried out by filtration with Whatman filter paper and the filtrate stored in sample cans in a refrigerator prior to analysis. Biosorption experiments were done separately for each adsorbent. The filtrate was analyzed in an UV-vis spectrophotometer for the final concentration of lead in aqueous solution and referring to the respective standardized graph. Finally the % biosorption of lead was calculated for each run as follows.

$$\%\ \text{biosorption} = [(C_i - C_f)/C_i] \times 100$$

where, C_i – initial concentration of lead in the solution
C_f – final concentration of lead in the solution.

Factors affecting metal bioremoval

To optimize the biosorption process, the batch experimental procedure was performed for different pH of the aqueous solution (2, 4, 6, 8, 10), amount of biosorbent dosage (1, 2, 3, 4, 5 g) and also for the adsorbent-metal contact time (30, 60, 90, 120). The effects of these parameters on % biosorption of lead (II) were obtained for each adsorbent. All the experiments were carried out in triplicates.

RESULTS AND DISCUSSION

The heavy metals of widespread concern to human health are lead, copper, mercury, cadmium, arsenic, chromium, as well as zinc [29]. Thus in present study explores the potentiality of two most commonly used plants, viz. *Phyllanthus emblica* (amla) seeds and *Psidium gujava* (guava) leaves for the biosorption of Pb (II) from aqueous solution under various conditions.

Effects of pH on biosorption

The pH of aqueous solution plays a significant role in the biosorption process. The pH of aqueous solution is the controlling factor in the adsorption process; hence it becomes necessary to determine the optimum pH at which maximum adsorption will takes place. pH affects the solubility of lead ion to a great extent. This is partially due to the fact that H^+ ions are strongly competing adsorbents. The pH affects the specification of metal ions and the ionization of surface functional groups [30]. Here a wide range of ph was used (2-10). Here results showed that biosorption was better at acidic pH compared to alkaline range for both biosorbents. In both cases optimum pH was found 4.0 with same amount of adsorbent. Figure 2 showed that amla seed increased biosorption of Pb (II) of 88 % where guava leaf powder showed biosorption 81 % at pH 4.0. At same pH, amla seed powder produced better biosorption than guava leaf as biosorbents.

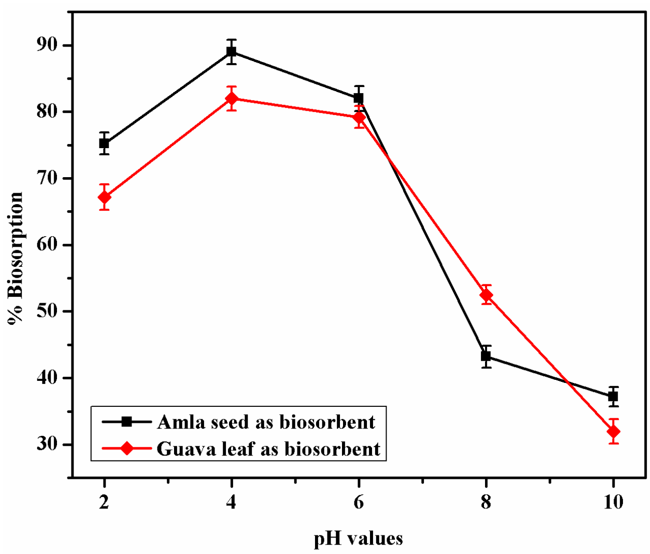

Figure 2: Effect of pH on biosorption of Pb (II) ion using seed powder of *Phyllanthus emblica* (amla) and leaf powder of *Psidium gujava* (guava)

Effects of biosorbent dosage on biosorption

Biosorbent dosage is one of the important parameter of adsorption. The effect of different biosorbent dosage (1-5 g/100 ml) was determined keeping other experimental condition constant, Pb(II) concentration (20 mg/100 ml), stirring speed (180 rpm), pH (4.0) and contact time (60 min) for both biosorbents. The outcome indicates (Figure 3) that increases in biosorbent dosage resulted in a higher biosorption of Pb (II). The adsorption efficiency was maximum at dose of 5 g/100 ml which is up to 96 % for amla seed and 85 % for guava leaf powder. It is evident from the results that the fraction of the metal removed from the aqueous phase increases with an increase in the adsorbent amount. Such behavior is obvious since the metal uptake capacity of the biosorbent increases as its dosage is increased. This is because of the number of active sites available for metal uptake would be more as the amount of the biosorbent increases [31].

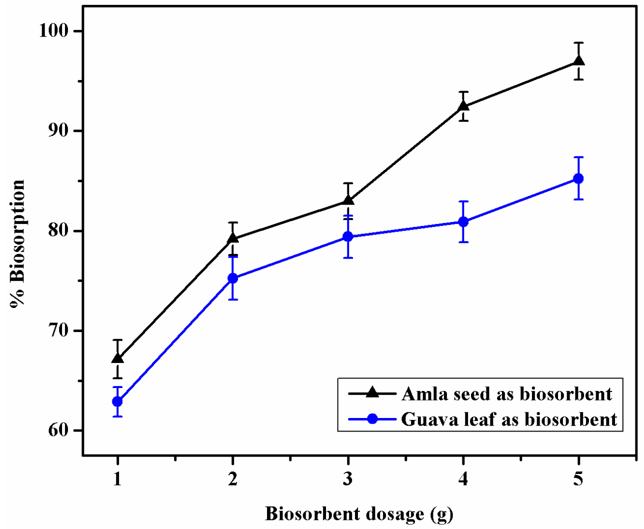

Figure 3: Effect of adsorbent dosage on biosorption of Pb (II) ion using seed powder of *Phyllanthus emblica* (amla) and leaf powder of *Psidium gujava* (guava)

Effects of contact time on biosorption

For the study on effect of contact time, a range of contact time (30-120 min) were used with other constant conditions of optimum pH 4.0, Pb (II) concentration (20 mg/100 ml), stirring speed (180 rpm), and 4 g/100 ml of biosorbent dosage. The results for the effect of contact time on adsorption of Pb (II) ion as shown in Figure 4 for the biosorbents. Graph shows that biosorption efficiency of Pb (II) ion increases with respect to increase in contact time of adsorbent. For amla seed and guava leaf powder, there was a progression in the rate of adsorption of lead ion maximum at 120 min of 98 % and 89 %, respectively. This may be due to the retention of heavy metals on adsorbent increased with increasing contact time for a fixed concentration of heavy metal and a fixed adsorbent mass [32].

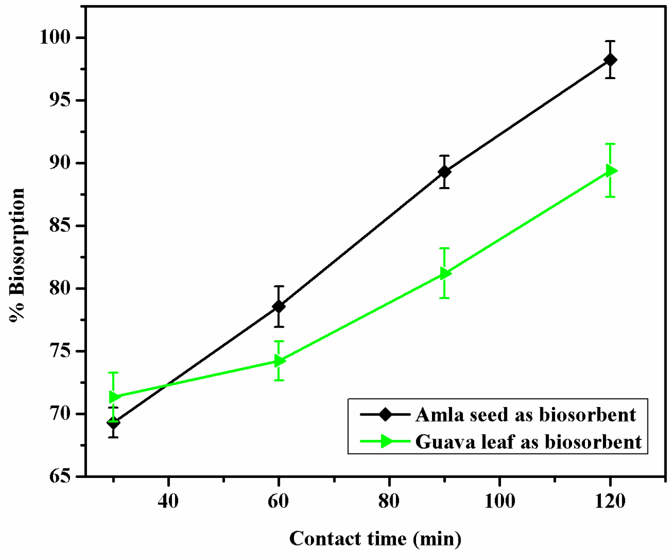

Figure 4: Effect of biosorbent dosage on biosorption of Pb (II) ion using seed powder of *Phyllanthus emblica* (amla) and leaf powder of *Psidium gujava* (guava)

CONCLUSION

The removal of metals from aqueous solutions using biosorption process has been an area of extensive research. From this study we can conclude that, both biosorbents showed significant biosorption efficiency of lead from synthetic solution. These biosorbents are very cheap, environment-friendly, thus they may be used in various industries before disposing off the metal waste. This study will be encourages further toxic metals remediation program and safe the environment in future.

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