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Removal of heavy metals (Cr^{6+}, Ni^{2+}) from polluted water using decaying leaves of plane (*Plantanus orientalis*)

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Abstract——Plane decaying leaves have been found capable of removing chromium and nickel ions from aqueous solutions. The removal efficiency depends upon the pH conditions, ions components and concentrations, and concentrations of leaves in media. The maximum removal for unique Cr^{6+} is about 7.5—8.0 g/kg leaves at pH 4.0, for unique Ni^{2+} about 2.6 g/kg at the region of PH5.0—5.5. Under the described conditions nickel increases chromium uptake by plane decaying leaves from solution.

Keywords: plane; decaying leaves; chromium; nickel; heavy metals.

1 Introduction

Plane tree, scientifically nominated *Plantanus orientalis*, is extensively planted in a large areas of China, especially in urban districts, for its luxuriant foliage in spring and summer. Nevertheless, while winter is coming, the luxuriant leaves are decaying and disturbing the environment. Since the decaying leaves consist of withered leaf tissues containing rich organic materials with a porous structure, they have a strong capability of absorption and can remove heavy metals from wastewater (Salim, 1985a).

Since heavy metals have been shown to be toxic to organisms and harmful to environment, it is of primary importance to find economic and effective ways to remove them from various heavy- metal-containing wastes for protection and decontamination of the environment. It has been reported that diversified decaying leaves are capable of removing nickel and aluminum from their aqueous solutions, and proved that the way is efficient in addition to its simplicity and availability. The relevant researches showed that decaying leaves of some plants, such as cypress, pine, pecan, oak and willow, removed significantly heavy metal ions of nickel and aluminum (Salim, 1985a; 1988b).

This study was initiated to examine the removal of heavy metal ions of chromium and

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nickel using decaying leaves of plane and to assess the effects of several factors including pH condition on the removal efficiency.

2 Material and methods

2.1 Material

The decaying leaves of plane (*P. orientalis*) for the experiments were collected from the neighborhood of the Wuhan University campus. The leaves were washed using fountain water and deionized water once separately and dried naturally. The chemical reagents for the study were all analytical grade agents. The bulk solutions of heavy metals used included (1) chromium-water: 200 ppm Cr^{6+} solution made up $K_2Cr_2O_7$, (2) 20 ppm Ni^{2+} solution made up $NiSO_4 . 7H_2O$, and (3) two types of nickel-chromium mixture solutions: one contains 200 ppm Cr^{6+} and 20 ppm Ni^{2+} and the other contains 200 ppm Cr^{6+} and 20 ppm Ni^{2+}.

2.2 Methods

The 500 ml Erlenmeyer flasks were used as containers in laboratory trials. These flasks were cleaned by filling them with 1.0 mol/L nitric acid for one week and then washed thoroughly with deionized water. 30g/1000ml leaves were added into the flasks filled with 250 ml specific heavy metal salt solutions for soaking. The removal of the studied elements in the solutions by decaying leaves was monitored by following the concentration changes of the heavy metal ions with time in a bulk solution in contact with a weight of pre-treated leaves. The reaction pH was adjusted using drops of 1.0 mol/L HNO_3 or NaOH as required. The quantitation of the heavy metals was gone through with an Atomic Absorption Spectrometer-model HITACHI-180-80. A pH S-2 acidometer was used for determining acidity of the leaves-solution system.

3 Results and analysis

3.1 Removal of Cr^{6+} from solutions by the leaves at different pH values

Removal of Cr^{6+} from solution at different pH values by plane decaying leaves. In laboratory the concentrations of chromium in the solutions at different pH values were determined in certain intervals. The losses of Cr^{6+} from 200 ppm solution at different pH values are shown in Fig. 1. The plane decaying leaves have a great capability of absorption of heavy metal Cr^{6-} and show a high efficiency of chromium removal from aqueous solutions with a close dependence upon the certain pH condition. As indicated in Fig. 1-b, the removal rate of Cr^{6+} at pH 3.0 — 6.4 grows exponentially in the initial 6 to 8 days and then becomes steady. In the pH>9.0 samples, changes of the removal rate curve seem to be a "S" feature, and the values are little comparatively.

The amount of chromium removed by an identified weight of leaves was plotted and presented as a function of pH in Fig. 2. The results suggested that the leaves have a greatest capability of removing Cr^{6+} in pH value of 4.0.

Nickel (Ni^{2+}) was removed from the identified 20 ppm $NiSO_4 . 7H_2O$ solutions by the decaying leaves of plane at different pH conditions. The changes of the nickel concentrations in

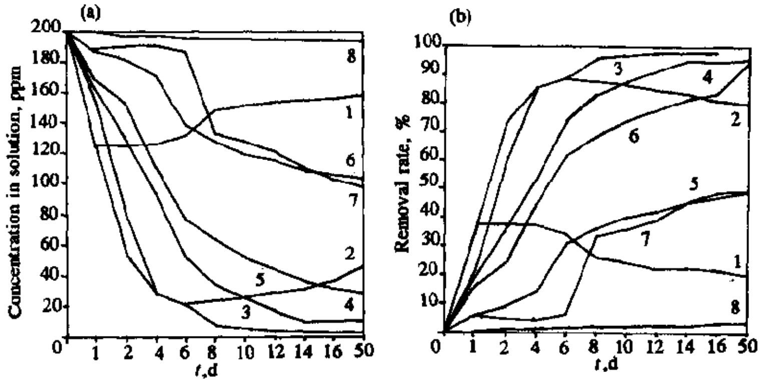

Fig. 1 Removal of chromium from 200 ppm aqueous solution using 30g/1000ml decaying leaves at different pH values

(a) 1. pH 2.0 2. pH 3.0 3. pH 4.0 4. pH 5.0—5.4
5. pH 6.4—6.7 6. pH 9.0—10 7. pH 12.5 8. Blank

(b) 1. pH 2.0 2. pH 3.0 3. pH 4.0 4. pH 5.0—5.5
5. pH 6.4—6.7 6. pH 9.0—10 7. pH 12.5 8. Blank

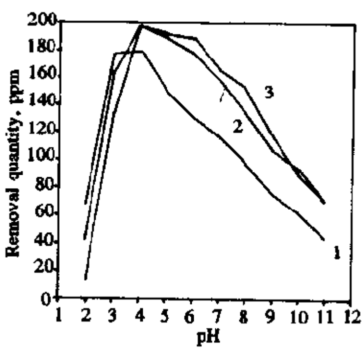

Fig. 2 Effects of pH values on removal efficiency of chromium from 200 ppm aqueous solution using 30g/1000ml leaves 1. 6th day 2. 16th day 3. 50th day

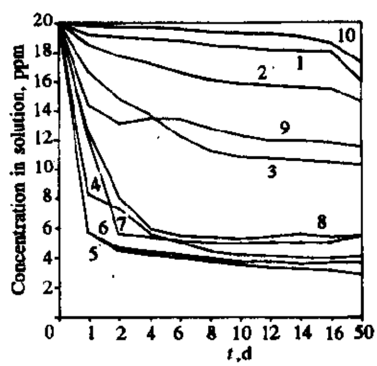

Fig. 3 Removal rate of nickel from 20 ppm aqueous solutions using 20g/1000ml decaying leaves 1. pH 2.0 2. pH 2.5 3. pH 3.5 4. pH 4.5 5. pH 5.0 6. pH 5.5 7. pH 6.5 8. pH 9.0 9. pH > 10.5 10. Blank

the processed solutions with time are shown in Fig. 3. The results indicate an obvious effect of the pH values on the nickel removal efficiency of plane decaying leaves. In the region of pH 5.0—10.0, the amount of loss of nickel by leaves studied here is dominant. A pH value for nickel maximum removal is 5.0—5.5, at which the tested lost rate in the first day is 72%, the 16th 83% and 50th 95%. The removal is much less in both very acidic (pH<3.5) and very basic (pH>10.5) media.

3.3 Removal of Cr^{6+} and Ni^{2+} from an aqueous complex by plane decaying leaves

Since the maximum amount of nickel and chromium losses from solutions by the leaves were at pH 4.0 and 5.0—5.5 respectively, the effect of the presence of Cr^{6+} and Ni^{2+} in an aqueous complex on the removal of themselves was studied using 30g/1000ml decaying leaves at pH 4.0 and pH 5.0—5.5, and are compared with their own loss individually. The results are shown in Fig. 4. These results indicate that the presence of Ni^{2+} ions at the region of pH 5.0—5.5 increases the Cr^{6+} loss in the 4th to 8th day, and nickel's own loss has insignificant variation.

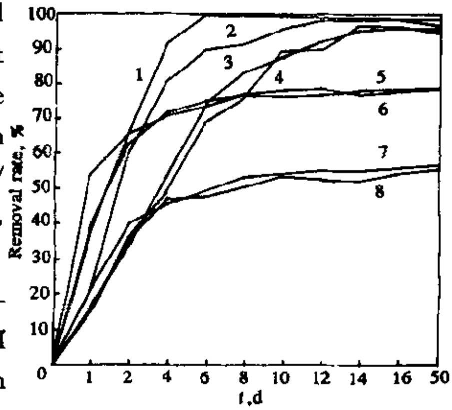

Fig. 4 Effects of chromium and nickel co-existence (200 ppm Cr^{6+} 200 Ni^{2+} ppm on their removal using 30g/1000ml leaves 1—4. Cr^{6+}; 5—8. Ni^{2+}; Of 8 lines, 3, 5 are unique ion; 4, 6 are complex; 1, 2, 7, 8 pH 4.0; 3, 4, 5, 6, pH 5.0—5.5

3.4 Effects of concentrations of the decaying leaves on the loss of chromium and nickel

Various concentrations of plane decaying leaves were used to take both the heavy metal ions from 200 ppm Cr^{6+} and Ni^{2+} solutions at pH 4.0 and 5.0—5.5, respectively. The results shown in Fig. 5 indicate that both Cr^{6+} and Ni^{2+} losses increased linearly with the increases of the concentrations of leaves in suspension, and the losses from solutions using various amounts of leaves were high in initial days and then slowed down. In the studies here the maximum removal of Cr^{6+} by plane decaying leaves is about 7.5—8.0g/1.0kg, for Ni^{2+} 2.6g/1.0kg.

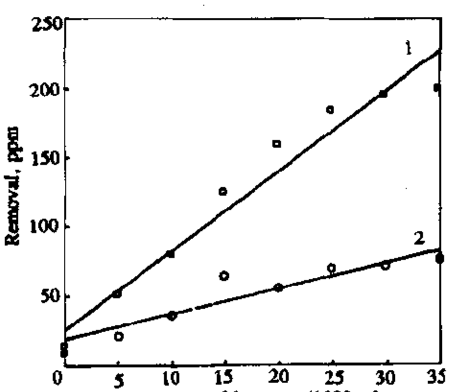

Fig. 5 Effect of concentrations of the decaying leaves on the loss of chromium and nickel

1. Cr^{6+}; 2. Ni^{2+}

4 Discussion

Plane decaying leaves were capable of effectively removing Cr^{6+} and Ni^{2+} from aqueous solutions with the results depending upon the pH and the ion components of media, the relative concentrations of leaves. The results were in correspondence with those from Salim *et al.* (Tahn, in press). The pH for maximum removal of unique Cr^{6+} is about 4.0, for unique Ni^{2+} is 5.0—5.5, which is lower than those of pine and oak decaying leaves (Salim, 1988b).

Under certain conditions Ni^{2+} is capable of increasing the removal of Cr^{6+} by leaves, which is different from the studies reviewed (Salim, 1988b; Tahn, in press). We consider that this may result from co-precipitation of metal ions.

Removal of heavy metal ions using plane decaying leaves also depends on the initial concentrations of metal ions, and is affected by the degrading elements of the leaves. The release of various degraded organics from leaves results in the increase of BOD and COD. The relevant problems are to be investigated in coming days.

Removal of heavy metals using plane decaying leaves may be used for treatment of various heavy metal wastewater. Since there is a huge reservoir of plane decaying leaves in China, these decaying leaves will be an useful resource for environmental protection.

Removal of heavy metals by the decaying leaves is resulted from the absorption capability of leaves. This also seems that the decaying leaves play a role in the process of geo-chemical cycle of heavy metal elements.

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