

## Adsorption of Indium and Gallium on Natural Banana Fiber

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Adsorption properties of indium and gallium ions were investigated and concentrations of metal ions measured by inductively coupled plasma atomic emission spectroscopy. The adsorption of indium ions by non-treated banana fiber increases with pH. The adsorption percentage of indium ion by non-treated banana fiber increases with increasing of pH. In the pH range between 1.0–2.0 and 3.5–5.0, adsorption of indium ion was 20%–40% and 40%–80%, respectively. For the case of gallium, there was no adsorption of gallium ions by non-treated banana fiber over the pH range 1.0–5.0. Such distinct behavior of these two metal ions raises the possibility of the utilization of banana fibers in the separation and adsorption of metal ions. It should be noted that it is not possible to separate  $\text{In}^{3+}$  or  $\text{Ga}^{3+}$  through the use of alkali-treated banana fiber.

### 1. Introduction

Over a billion banana stalks are thrown away every year. Recently, banana fiber has attracted attention as an inedible natural resource. As a result, the effective use of banana fiber has been studied as a valuable recyclable biomass material. In previous studies, banana fiber/poly(butylene succinate) composites using hexamethylene diisocyanate as a reactive compatibilizer, were investigated [1]. It was found that alkali treatment of banana fibers and an addition of hexamethylene diisocyanate improved the adhesion between banana fibers and poly(butylene succinate). It is therefore both important and interesting to investigate other uses of banana fibers. Several methods have been developed to collect and separate metal ions, including ion-exchange and solvent extraction techniques. In particular, environmentally friendly ion-exchange systems and the use of chelated materials to collect and separate metal ions, have been investigated by many researchers. Gupta et al., reported that banana fibers were used as an adsorbent for the removal of malachite green dye [2]. Haris and Sathasivam reported that banana fibers were used as an adsorbent for the removal of methyl red from aqueous solutions [3–4]. However, as far as it is known, the investigation of banana fibers (or chemically modified banana fibers) for use as an adsorbent for various metal ions, has not been reported. In recent studies carried out by this research group, the adsorption properties of modified and non-modified banana fiber with respect to transition metal ions, rare metal ions and cesium ions have been evaluated [5–7]. Rare metals are important in many fields in particular that of advanced material

science where their application has increased significantly. In the present study, the adsorption properties of banana fibers with respect to indium and gallium were evaluated. Results obtained show the possibility of utilizing banana fibers as an efficient adsorbent for metals ions.

## 2. Experimental

### 2.1 Materials

Non-treated banana fiber (Figure 1) was obtained from the Republic of the Philippines and used without further purification or surface treatment. Alkali-treated banana fiber was obtained by treating 100 g of banana fiber with 3.0 dm<sup>3</sup> of 20 wt% NaOH aqueous solution (aq) at room temperature for 2 hours [7]. The resulting alkali-treated banana fiber (Figure 2) was washed with water and dried overnight in a vacuum oven at 70 °C. All chemicals were purchased and used without further purification.



Figure 1. Non-treated banana fiber.



Figure 2. Alkali-treated banana fiber.

### 2.2 Adsorption of indium and gallium ions by non-treated banana fiber or alkali-treated banana fiber

Non-treated and alkali-treated banana fibers were cut into 5 mm lengths (Figure 3 and 4).

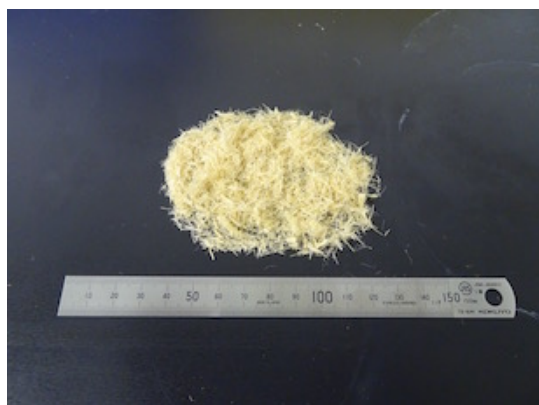


Figure 3. Non-treated banana fiber. The banana fiber was cut into the lengths of 5 mm.



Figure 4. Alkali-treated banana fiber. The banana fiber was cut into the lengths of 5 mm.

Aqueous solutions were prepared containing  $1.0 \times 10^{-4}$  mol dm<sup>3</sup> metal ions ( $\text{In}^{3+}$  and  $\text{Ga}^{3+}$ ),  $1.0 \times 10^{-1}$  mol dm<sup>3</sup> sodium perchlorate and  $1.0 \times 10^{-2}$  mol dm<sup>3</sup> acetic acid. A 30 cm<sup>3</sup> aliquot of each solution, along with 0.3 g of the metal ion adsorbent, was placed into plastic tubes. The tubes were shaken at room temperature for five days. This time length was selected for the purpose of comparison with previously unpublished work completed in this research group. On completion of the reaction, the mixed solutions were filtered. The concentration of the metal ions was then measured by an inductively coupled argon plasma atomic emission spectroscope (ICP-AES). The pH value of the aqueous phase was measured by a pH meter equipped with glass electrodes.

### 2.3 SEM observation

The surface of the banana fibers was investigated through the use of a scanning electron microscope (SEM).

### 2.4 Characterization of non-treated and alkali-treated banana fiber

The FT-IR spectra were obtained with the use of a FT-IR spectrometer.

## 3. Results and Discussion

### 3.1 Adsorption of indium and allium ions by non-treated banana fiber

Figure 5 shows the percentage adsorption of  $\text{In}^{3+}$  and  $\text{Ga}^{3+}$  as a function of pH. The adsorption of  $\text{In}^{3+}$  increases with pH with 20%–40% adsorption in the pH range 1.0–2.0. Adsorption of 70%–80% was observed in the pH range 3.5–5.0 and maximum adsorption of approximately 90% was seen at pH 3.0. In the case of  $\text{Ga}^{3+}$  no adsorption was observed over the pH range 1.0–5.0. These results therefore show good separation of  $\text{In}^{3+}$  and  $\text{Ga}^{3+}$  ions over the pH range 1.2–5.0. Lignins or other functional group originating from banana fiber are considered to be the adsorption sites of  $\text{In}^{3+}$  ions.

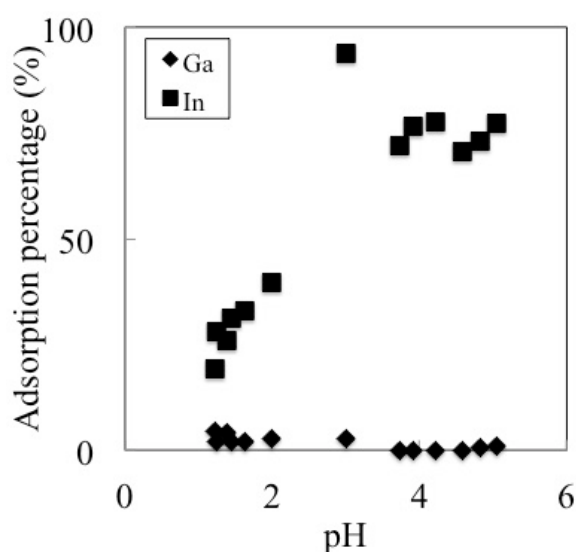


Figure 5. Effect of pH on the adsorption of  $\text{In}^{3+}$  and  $\text{Ga}^{3+}$  ions by non-treated banana fiber [9].

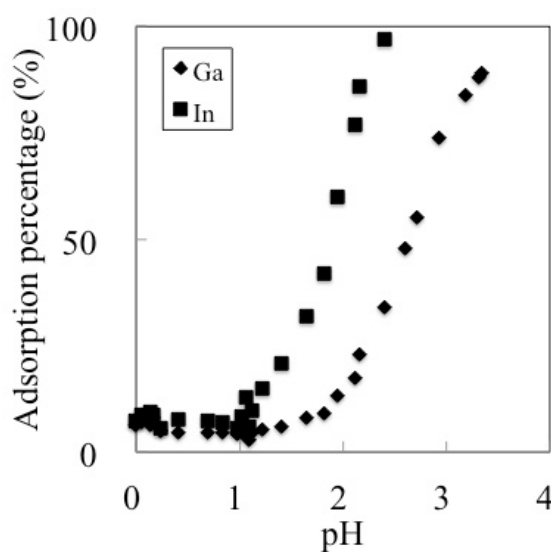


Figure 6. Effect of pH on the adsorption of  $\text{In}^{3+}$  and  $\text{Ga}^{3+}$  ions by alkali-treated banana fiber [9].

### 3.2 Adsorption of indium and gallium ions by alkali-treated banana fiber

Figure 6 shows the percentage adsorption of  $\text{In}^{3+}$  and  $\text{Ga}^{3+}$  as a function of pH. Adsorption properties of  $\text{In}^{3+}$  show approximately 100% adsorption at pH 2.3. A pH of 2.0 corresponds to 60% adsorption, while in the pH range from 0.1 to 1.0, no adsorption occurred. Adsorption properties of  $\text{Ga}^{3+}$  show approximately 90% adsorption at pH 3.4. A pH of 2.8 corresponds to 50% adsorption, while in the pH range 0.1 to 1.3, no adsorption occurred. These results indicate the possibility of utilizing banana fibers as a rare metal ion adsorbent. Because of the adsorption properties of alkali-treated banana fiber with respect to  $\text{In}^{3+}$  and  $\text{Ga}^{3+}$ , this material does not act as an efficient separator and adsorber of these metal ions.

### 3.3 Difference between non-treated and alkali-treated banana fibers

The SEM images of the surface of non-treated and alkali-treated banana fibers are shown in Figure 7 and 8. The banana fibers purchased from the Republic of the Philippines were virtually untreated. They were only washed with soap and water thereby leaving much of the lignin and hemicellulose intact. Banana fibers comprise approximately 9% lignin, 39% hemicellulose, 43% cellulose, and many other compounds [8]. The smooth surfaces of the banana fibers transformed into a wavy morphology after alkali treatment and the lignin and hemicellulose originally from the banana fiber were removed by this treatment. Consequently, originated from the cellulose existed on the surfaces of the alkali-treated banana fiber.

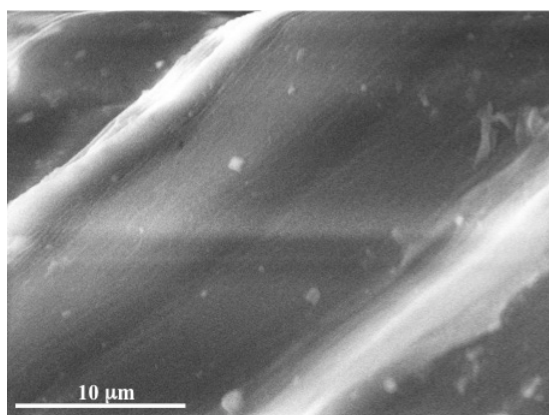


Figure 7. SEM image of non-treated banana fiber.

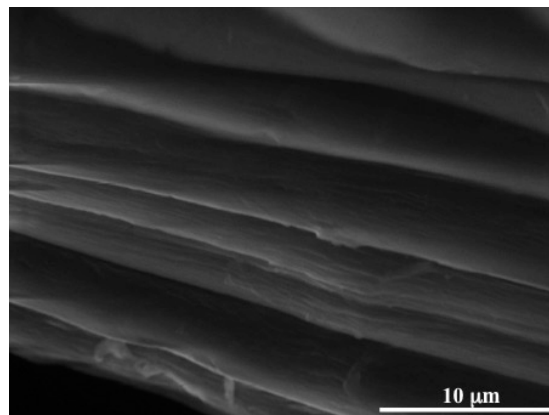


Figure 8. SEM image of alkali-treated banana fiber.

Lignin in banana fiber was identified with FT-IR. Figure 9 shows FT-IR spectra of non-treated and alkali-treated banana fibers. The two spectra show different bands around  $1620\text{ cm}^{-1}$  and these are due to C=C groups found in lignin. Lignins or other functional groups originating from banana fiber are considered the adsorption sites of  $\text{In}^{3+}$  and  $\text{Ga}^{3+}$ . Almost all lignin present in the banana fiber was removed by sodium hydroxide alkali treatment. This factor is considered to explain the observed differences in the adsorption behavior of non-treated and alkali-treated banana fiber. However, the exact adsorption mechanism of the metal ions into banana fiber could not be analyzed in detail.

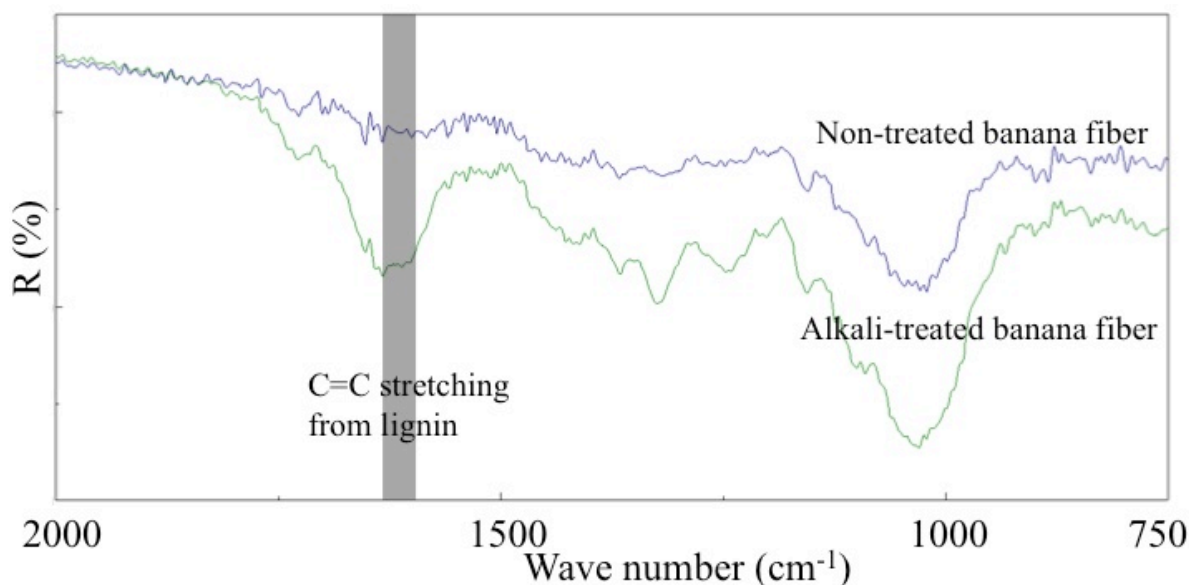


Figure 9. FT-IR spectra of non-treated and alkali-treated banana fibers.

#### 4. Conclusion

The adsorption of indium ions ( $\text{In}^{3+}$ ) by non-treated banana fiber increases with pH. An adsorption of 20%–40% is observed in the pH range 1.0–2.0. For the pH range 3.5–5.0 an adsorption of 70%–80% is seen. A maximum adsorption of 90% is measured at pH 3.0. In the case of gallium ions ( $\text{Ga}^{3+}$ ) and non-treated banana fiber, no adsorption was observed over the pH range 1.0–5.0. Due to the different adsorption behavior of untreated banana fiber over the pH range 1.0–5.0 for the ions  $\text{In}^{3+}$  and  $\text{Ga}^{3+}$ , the possibility of utilizing this material as an adsorbent and separator for these metal ions is illustrated. Results showed that alkali-treated banana fiber cannot function in a similar manner.

#### Acknowledgment

This research was supported by the Environment Research and Technology Development Fund (3K143003) of the Ministry of the Environment, Japan.

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