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KOH-activated dragon fruit peels for Cd^{2+} ions adsorption from water

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ABSTRAK

Penelitian ini mempelajari potensi kulit buah naga yang diaktivasi dengan KOH sebagai adsorben untuk penurunan kadar ion Cd^{2+} dalam larutan. Kemampuan adsorpsi kulit buah naga yang diaktivasi dievaluasi melalui percobaan adsorpsi sistem batch, di mana berbagai parameter termasuk dosis adsorben, konsentrasi awal Cd^{2+}, waktu kontak, dan pH larutan dipelajari. Kondisi optimum untuk proses adsorpsi adalah pH 5, waktu pengadukan 120 menit, dan dosis adsorben sebesar 20 mg (dalam 25 mL larutan). Hasil penelitian ini menunjukkan potensi pemanfaatan bahan limbah pertanian, seperti kulit buah naga, sebagai adsorben yang efektif dan berkelanjutan untuk penghilangan ion logam berat dari sumber air dan dapat berkontribusi pada upaya remediasi lingkungan.

Kata Kunci: *Adsorpsi, Aktivasi KOH, Kadmium, Kulit Buah Naga*

ABSTRACT

This study investigates the potential of KOH-activated dragon fruit peels as an adsorbent for the removal of Cd^{2+} ions from solution. The adsorption performance of the activated dragon fruit peels was evaluated through batch adsorption experiments, where various parameters including adsorbent dosage, initial Cd^{2+} concentration, contact time, and solution pH were examined. The optimum condition for the adsorption process was pH 5, stirring time 120 min, adsorbent dosage of 20 mg (in 25 mL solution). The findings highlight the potential of utilizing agricultural waste materials, such as dragon fruit peel, as an effective and sustainable adsorbent for the removal of heavy metal ions from water sources, contributing to environmental remediation efforts.

Keywords: *Adsorption, Cadmium, Dragon fruit peel, KOH activation*

I. INTRODUCTION

Heavy metal pollution is a significant environmental concern due to its detrimental effects on ecosystems and human health. Among heavy metals, Cadmium (Cd) is one of the most toxic heavy metals and known to have no biological function [1]. Cd is primarily generated from industrial activities such as mining and battery production. The accumulation of Cd in the environment poses serious threats and can ultimately endanger organisms through food chain contamination. The allowable limit for Cd in drinking water by World Health Organization is 0.003 mg/L. In Indonesia, the permissible limit for Cd in raw water sources for drinking water is 0.01 mg/L [2] Therefore, it is of great importance to remove Cd from aquatic environments.

Among various treatment technologies for Cd removal from water, adsorption technique is known to be the most promising, cost-effective, simple, effective, and environmentally friendly [3]. Researchers have been exploring the use of various biomass as an economical and environmentally friendly adsorbent for adsorption process [4]. Biomaterials contain many components such as carbohydrates, cellulose, and phenolic compounds that can provide the binding sites for removing heavy metal ions [5-6]. One such potential candidate of biosorbent is dragon fruit peel, which is rich in organic compounds, such as phenolic compounds, betacyanin, betalains [7]. The presence of O-H, C=O, C=C functional groups in such compounds can be used for heavy metal ions adsorption.

In this study, the dragon fruit peel was activated using KOH as an activating agent and used as an adsorbent for Cd^{2+} ions in water. The activation of these fruit peels using alkaline agents such as potassium hydroxide (KOH) has been shown to enhance their adsorption capacity by increasing surface area and introducing functional groups. This study aims to investigate the potential of KOH-activated dragon fruit peels as an effective adsorbent for the removal of Cd^{2+} ions from water. Through batch adsorption experiments, the adsorption performance of the activated dragon fruit peels will be evaluated under various operating conditions, including adsorbent dosage, initial Cd^{2+} concentration, contact time, and pH of the solution.

II. RESEARCH METHOD

2.1. Preparation and characterization of adsorbent

Dragon fruit peel waste was collected from the local area of Yogyakarta. The peel was washed thoroughly with water to remove dirt and was cut into a bite-size piece (3 cm x 3 cm). The peel then was dried to constant weight at 105°C to remove the water content. After that, the peel was ground to form powder and was sieved using a 100-mesh size sieve. The activation process was carried out by immersing the dragon fruit peel powder (100 gram in 100 mL KOH) in 0.1 M KOH solution (Sigma Aldrich, Germany). The immersion was carried out without stirring for 24 h. After that, the powder was washed with distilled water to constant pH and was dried at 105°C. The characterization of the adsorbent was performed using Fourier Transform Infrared (FTIR) Spectroscopy (Shimadzu, IRTracer-100) and Scanning Electron Microscopy (SEM; Thermo Fisher Scientific, Phenom ProX).

2.2. Batch adsorption test

Adsorption studies were carried out in a batch system. Twenty five milliliters of Cd^{2+} solution prepared from Cd $(NO_3)_2$ powder (Sigma Aldrich, Germany) was added by a known mass of the adsorbent and was stirred for 120 min. Some adsorption parameters were varied such as dosage of adsorbent (5, 10, 20, and 30 mg in 25 mL solution), pH (3, 5, 7, 9), initial concentration of Cd^{2+} (10, 30, 50, 100, 150, 200, and 250 mg/L), and stirring time (5, 10, 20, 30, 60, 90, and120 min).

After the adsorption process, the solution was filtered using a Whatmann filter paper and cadmium ions remaining in the solution was measured using an atomic absorption spectrophotometer (GBC, Avanta). The removal efficiency of the adsorption process was calculated using Eq. 1.

$$\text{Removal efficiency}(\%) = \frac{C_i - C_t}{C_t} \times 100\%. \quad \text{(Eq. 1)}$$

III. RESULTS AND DISCUSSION

3. 1. Characteristics of adsorbent

FTIR analysis of the dragon fruit peel powder both the raw and the KOH-activated were performed to elucidate the functional groups presented in the materials. FTIR spectra of the adsorbent was given in **Figure 1**. It is seen that no significant change of FTIR spectra of the dragon fruit peel after KOH activation. It suggests that the functional groups of the adsorbent after KOH activation remain the same. Absorption peak at 1645 cm^{-1} was assigned to carbonyl groups (C=O) and carboxylate anions (COO-) stretching vibrations, indicating the presence of pectin in dragon fruit peel [8]. Absorption peak at 2999 cm^{-1} was corresponded to C-H stretching vibration of methyl esters [9].

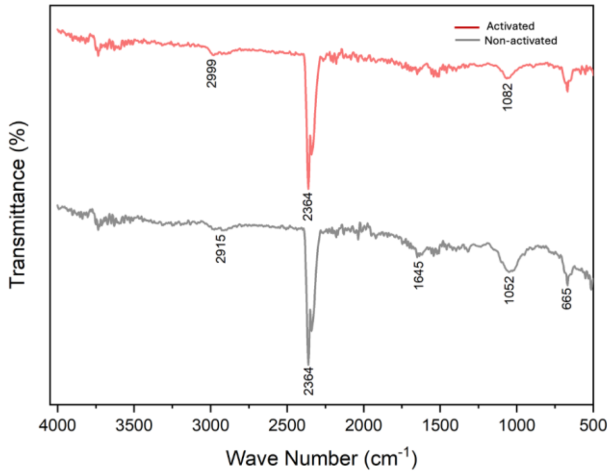

Figure 1:.FTIR spectra of KOH-activated and non-activated dragon fruit peel powder.

The surface morphologies of dragon fruit peel before and after the activation with KOH were presented in **Figure 2**. The activation using KOH is to remove the impurities in the pores of the material so that it could be more efficient for adsorption process.

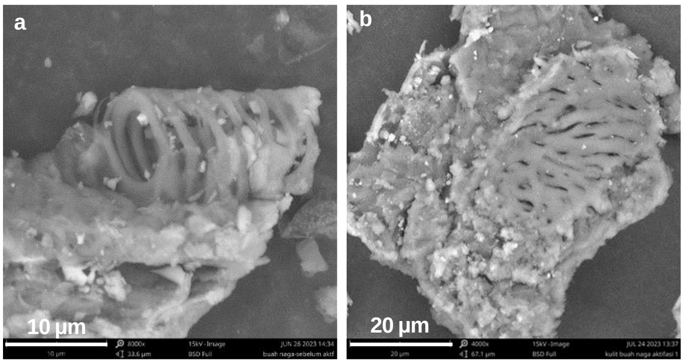

Figure 2: SEM images of non-activated (a) and KOH-activated (b) dragon fruit peel adsorbents

3. 2. Adsorption process

The effect of adsorbent mass in the removal efficiency of Cd^{2+} from solution is given in **Figure 3**. It is seen that the increase of adsorbent mass is followed by the increase of adsorption capacity until 20 mg (solution volume is 25 mL). However, above 20 mg, the efficiency of adsorbent decreases due to the aggregation of adsorbent particles in the solution causing the decrease of surface area of adsorbent for Cd^{2+} adsorption [10]. Therefore, the adsorption process is conducted using 20 mg adsorbent.

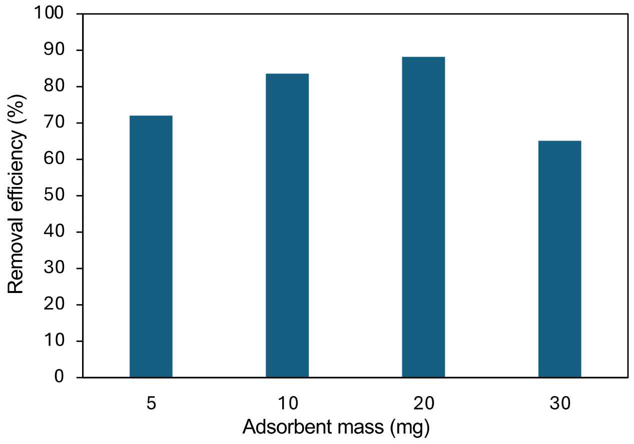

Figure 3: Effect of adsorbent mass on removal efficiency

The surface charge of the adsorbent as well as cadmium species are highly dependent on solution pH. The effect of pH on removal efficiency of Cd^{2+} ions using KOH-activated dragon fruit peel is shown in **Figure 4**. The removal efficiency increases with the increase of solution pH from 3 to 5, while the removal efficiency remains relatively constant above pH 5. At higher pH, the functional groups of the adsorbents become negatively charged due to the deprotonation process. The negatively charged adsorbent will cause an optimum interaction with Cd^{2+} ions [11].

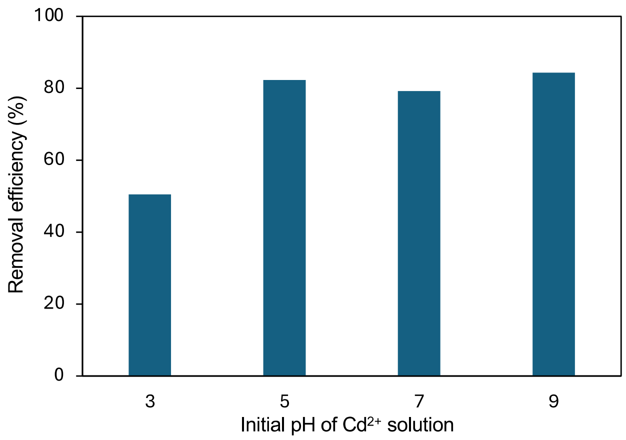

Figure 4: Effect of initial solution pH on removal efficiency

The effect of interaction time on the adsorption process is given in **Figure 5**. It is seen that no obvious trend on the effect of interaction time on the removal efficiency of the adsorbent towards Cd^{2+} ions. This could be because the heterogeneity of the adsorbent surface that leads to the variations in adsorption kinetics over time. Different sites on the surface may provide different affinities for Cd^{2+} ions, leading to a complex adsorption process. In this study, 120 min was chosen as the optimum time for adsorption.

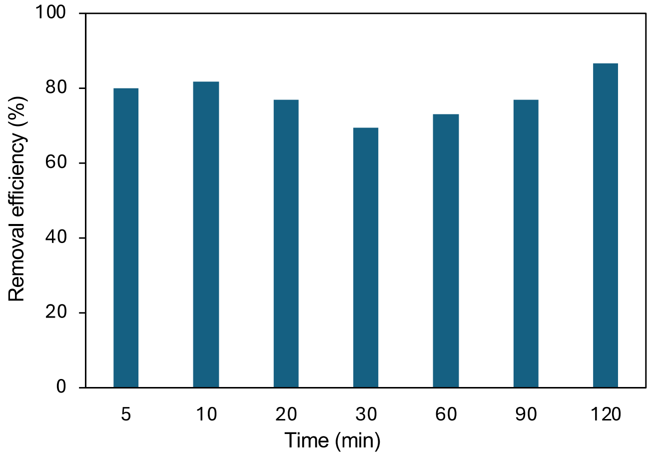

Figure 5: Effect of interaction time on removal efficiency of adsorption

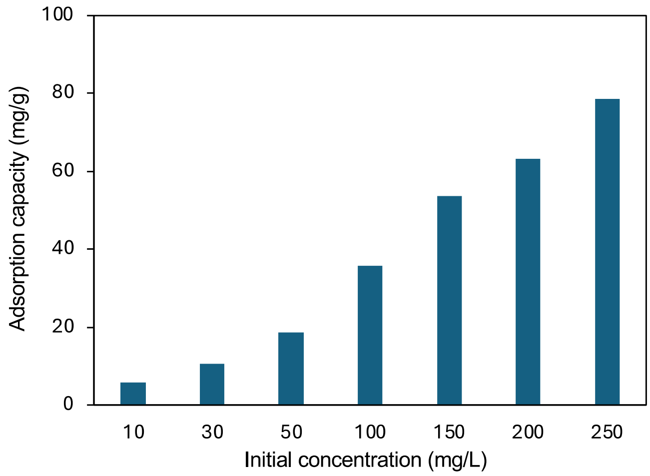

Figure 6: Effect of initial concentration of Cd^{2+} on adsorption capacity of the adsorbent

Figure 6 shows that the adsorption capacity of KOH-activated dragon fruit peel adsorbent for Cd^{2+} ions increase with the increase of initial concentration of Cd^{2+}. The reason is that the higher the concentration of Cd^{2+} ions, the higher the possibility of the collision between Cd^{2+} ions as the adsorbate and the adsorption site of the adsorbent. In addition, the higher Cd^{2+} concentration, the better the driving force of mass transfer [12].

3. 3. Comparison of the non-activated and KOH-activated adsorbent

The ability of KOH-activated dragon fruit peel to remove Cd^{2+} ions from water at optimum condition (pH 5, 120 min, 20 mg adsorbent) was compared to the non-activated dragon fruit peel as shown in **Table 1**. The KOH-activated adsorbent shows significantly higher removal efficiency for Cd^{2+} ion. This implies that the activation using KOH may remove the impurities that clogged the pores of raw dragon fruit peel. Similar works also reported that the activation of adsorbent materials using KOH can enhance the adsorption capacity of the adsorbent materials [13-14].

Table 1: The removal efficiency of the non-activated and KOH-activated dragon fruit peel towards Cd^{2+} ions

Adsorbent	Removal efficiency (%)
KOH-activated dragon fruit peel	96.7
Non-activated dragon fruit peel	76.7

IV. CONCLUSION

KOH-activated dragon fruit peels show a significant potential as an adsorbent for the removal of Cd^{2+} ions from solution. The KOH-activated dragon fruit peel can remove Cd^{2+} ions from solution with the optimum adsorption conditions of pH 5, stirring time of 120 minutes, and adsorbent dosage of 20 mg in 25 mL solution. These findings indicate that agricultural waste materials such as dragon fruit peels hold promise as an effective and sustainable adsorbent for addressing heavy metal ion pollution in water environments.

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