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# UTILIZATION OF BANANA PEEL WASTE IMPREGNATED INTO PVA/ALGINATE POLYMERIC BEADS FOR COPPER(II) ION ADSORPTION

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**Abstract:** *Globally, environmental pollution is a major topic because it affects the balance of the ecosystem. Banana peel waste is one of the major organic pollutants found in Indonesia. To minimize the waste, banana peel waste is used as an adsorbent for inorganic pollutants removal such as copper(II) ions. However, considering the small size of the banana peel waste, it was impregnated into PVA/Alginate polymeric beads to increase the particle size. Thus, it can be easily separated from the aqueous solution after extraction. The SEM image shows the morphology of PVA/Alginate polymeric beads impregnated with and/or without banana peel waste with different morphology in cavity and pore. The amount of banana peel waste impregnated into polymeric beads affected the mechanical strength and density of the polymeric beads. The optimum working pH for copper(II) ion adsorption using polymeric beads was 4 with the extracted amount of copper(II) is 1.383 mmol/g. The higher the initial concentration of copper(II) ion present in the solution, the higher amount of copper(II) ion extracted into the polymeric beads and reached the equilibrium condition at a higher initial concentration of copper(II) ion. It can be concluded that the impregnation of banana peel waste into the PVA/Alginate polymeric beads affected the morphology of polymeric beads by forming a hollow pore inside the polymeric beads, polymeric beads well-worked at the acidic condition and the*

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*equilibrium condition of copper(II) ion adsorption achieved at a higher initial concentration of copper(II) ion in the solution.*

**Keywords:** *PVA/Alginate, Banana peel, Copper(II) ion*

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## Introduction

Environmental pollution always becomes a primary concern for government, academicians, researchers, and scientists because it affects the balance of the ecosystem. Environmental pollution is caused by the presence of pollutants, whether organic or inorganic pollutants, in the environment. Banana peel is one of the organic wastes that can be found abundantly in Indonesia.

According to the Central Bureau of Statistics of Indonesia, the production of bananas is contiuously increasing every year and the consumption of bananas increased by a percentage of consumption around 33.81% in 2020. Thus, to control the increase of banana peel waste in the environment, it is better to utilize banana peel waste as a biosorbent for copper(II) ion removal. Considering the existence of organic compounds in banana peel, many researchers utilize banana peel as a biosorbent for organic pollutants (Achak et al., 2009; Mohammed & Chong, 2014; Aliyu et al., 2015; El-Din et al., 2017; Thani et al., 2017; Singh et al., 2018; Dawodu et al., 2021; Maheshwari et al., 2023; Hock et al., 2023) and inorganic pollutants (Kaewsam et al., 2008; Hossain et al., 2012a; Hossain et al., 2012b; Oyewo et al., 2016; Motaghi & Ziarati, 2016; Li et al., 2016; Oyewo et al., 2017; Fabre et al., 2020; Lavanya et al., 2022; Singh & Datta, 2022; ). Thus, the purpose of this study is the utilization of organic pollutants (banana peel waste) which abundantly exist in Indonesia as biosorbents for inorganic pollutants removal such as copper(II) ion. However, the small size of the banana peel (usually in micro or nano) leads to the difficulty in the separation of the banana peel from the aqueous solution. Therefore, banana peel waste was impregnated into the PVA/Alginate polymeric beads to ease the separation of the adsorbent from the aqueous solution.

## Literature Review

Alginate is an anionic polysaccharide that can be obtained from algae. Alginate contains two functional groups, hydroxyl and carboxyl, which can be acted as donor ligands to metal ions and form a complex molecule with the metal ion. Therefore, alginate has been widely used as an adsorbent to bind a metal ion. Furthermore, alginate has the ability to form a hydrogel and widely be used as an encapsulant to impregnate organic substances (Xiao et al., 2019; Liu et al., 2020). However, alginate hydrogel is fragile and easy to break thus the alginate hydrogel is crosslinked with polyvinyl alcohol (PVA) using calcium chloride ($CaCl_2$) to strengthen the wall of the polymeric beads (Komatsu et al., 2015; Martínez-Gómez et al., 2017; Yi et al., 2018; Inda et al., 2018; Shivakumara & Demappa, 2019; Xiao et al., 2019).

PVA is a synthetic polymer that can stabilize the alginate polymer beads by considering biocompatibility, high elasticity, and high mechanical strength (Xiao et al., 2019). PVA has been widely used as a crosslinker together with alginate to increase the mechanical strength of the polymeric material by forming a hydrogen bond (Guajardo, 2023; Rahman et al., 2023).

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## Materials and methods

### Materials

Materials used in this study are banana peel, polyvinyl alcohol, sodium alginate, NaOH, $HNO_3$, $CaCl_2$, $CuSO_4$ 5 $H_2O$.

### Methods

#### Preparation of Banana Peel Waste

Ripen banana peel waste was collected in the local market in Palu, Indonesia. The collected ripened banana peel waste was washed with groundwater and distilled water respectively. Clean ripen banana peel waste was dried under the sun until the color turned to brown. Dried banana peel waste was cut into pieces, grind, immersed in NaOH for 6 hours, then washed using distilled water until pH 7. Furthermore, the banana peel waste was immersed in $HNO_3$ for 6 hours and washed using distilled water until pH 7 (Oyewo, et al., 2017).

#### Synthesis of PVA/Alginate Polymeric Beads Impregnated with Banana Peel Waste

Various amounts of banana peels are impregnated into a homogeneous mixture of PVA, alginate, and distilled water by adding and stirring for 4 hours until homogenous. The homogenous mixture containing banana peel was dropped into a calcium chloride solution using a syringe and stored for 24 hours. The crosslinked polymeric beads were filtered and washed with distilled water.

#### Observation of PVA/Alginate Polymeric Beads Impregnated with Banana Peel Waste

The morphology of the obtained polymeric beads was observed using Scanning Electron Microscopy Hitachi Flexsem 1000.

The mechanical strength of the polymeric beads was measured using Hydraulic Impact Resistance (Du, et al., 2021).

The density of polymeric beads was determined by putting the polymeric beads into 4 mL water and observing the increase in water volume.

#### pH Effect on Copper(II) Ion Adsorption using PVA/Alginate Polymeric Beads Impregnated with Banana Peel Waste

0.2 grams of polymeric beads were put into the 30 mL of $CuSO_4$ 10 ppm with various pH and shaken for 24 hours. After the extraction process, the polymeric beads were filtered and $CuSO_4$ solution was measured using atomic adsorption spectrophotometer (Inda, et al., 2017).

#### Effect of Initial Concentration on Copper(II) Ion Adsorption using PVA/Alginate Polymeric Beads Impregnated with Banana Peel Waste

0.2 grams of polymeric beads with various amounts of banana peel impregnated into polymeric beads were put into the 30 mL of $CuSO_4$ with various initial concentrations of $CuSO_4$ solution, 0-500 ppm. The extraction process of copper(II) ion was carried out for 24 hours, filtered, and measured using atomic adsorption spectrophotometer (Inda, et al., 2017).

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## Results and Discussions

### Characteristics of PVA/Alginate Polymeric Beads Impregnated with Banana Peel Waste

#### Morphology of PVA/Alginate Polymeric Beads

PVA/Alginate polymeric beads impregnated with various amounts of banana peel waste were successfully synthesized. The synthesized PVA/Alginate polymeric beads impregnated with various amounts of banana peel waste was shown in Figure 1. Figures 1 (a) & (b) show the light brown color of the polymeric beads with 1 gram and 1.5 g of banana peel waste. Figures 1 (c) and (d) show the color of PVA/Alginate polymeric beads is dark brown. We can assume that the color of the polymeric bead will be significantly changed to dark brown by increasing the amount of banana peel waste impregnated into the polymeric beads. Those pictures show that the banana peel waste was successfully impregnated into PVA/Alginate polymeric beads.

PVA/Alginate polymeric beads with and/or without banana peel waste were observed using Scanning Electron Microscopy (Figure 2). The SEM images show that banana peel waste (Figure 2a) has an irregular shape with a slightly smooth surface like a stone, solid structure, and cavities on the surface of banana peel waste. Whereas, PVA/Alginate polymeric beads without banana peel waste show a rough surface and cavities with irregular structures on the surface of polymeric beads (Figure 2b). Figure 2c is a representative of PVA/Alginate polymeric beads impregnated with 2.5 g of banana peel waste. The SEM image shows a vesicle surface of a polymeric bead by considering the existence of banana peel waste inside the polymeric bead. The existence of banana peel waste inside the polymeric bead affected the morphology of the polymeric bead as shown in Figure 3 (a) and (b), cross-section images.

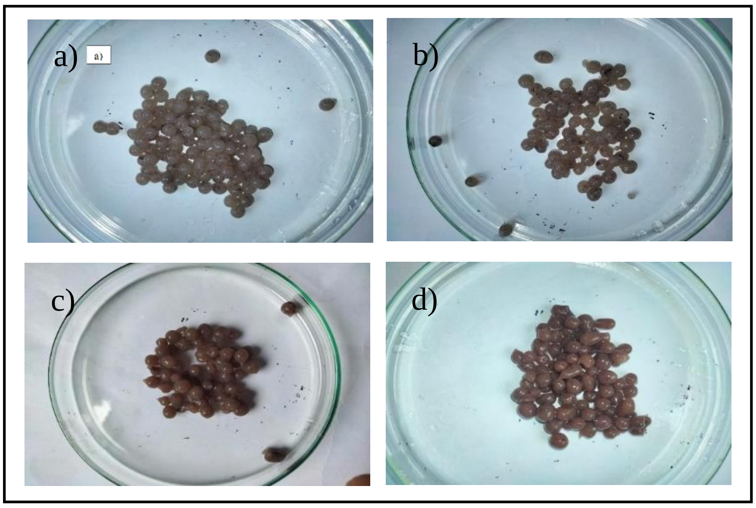


**Figure 1: Synthesized PVA/Alginate Polymeric Beads impregnated with (a) 1 g; (b) 1.5 g; (c) 2 g; and (d) 2.5 g Banana Peel Waste**

The cross-section images show the different structures between PVA/Alginate polymeric beads with and/or without banana peel waste. The SEM image of the PVA/Alginate polymeric bead containing 2.5 g of banana peel waste shows many hollow pores formed in the polymeric bead. Whereas, the SEM image of the PVA/Alginate polymeric bead without banana peel waste shows pores with small size and cave-like pores inside the polymeric bead. It can be assumed that the addition of banana peel waste inside the polymeric bead can affect the morphology of

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the PVA/Alginate polymeric bead and also form a hollow pore with a larger pore size than polymeric bead without banana peel waste.

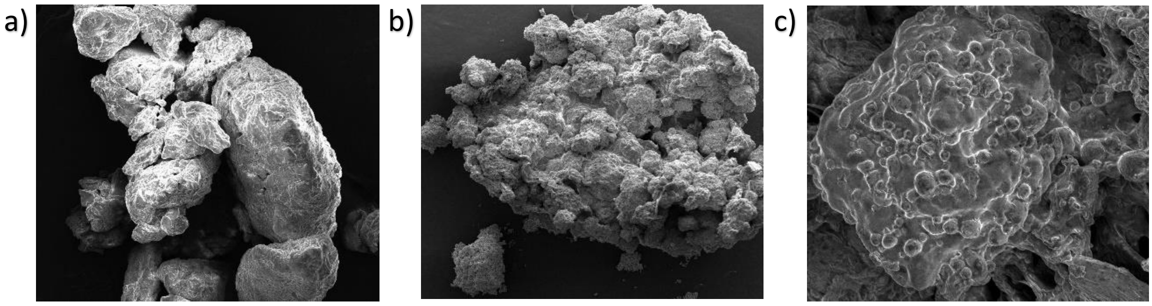


**Figure 2: SEM Images of (a) Banana Peel Waste; (b) PVA/Alginate Polymeric Beads without Banana Peel Waste; (c) PVA/Alginate Polymeric Beads with 2.5 g of Banana Peel Waste**

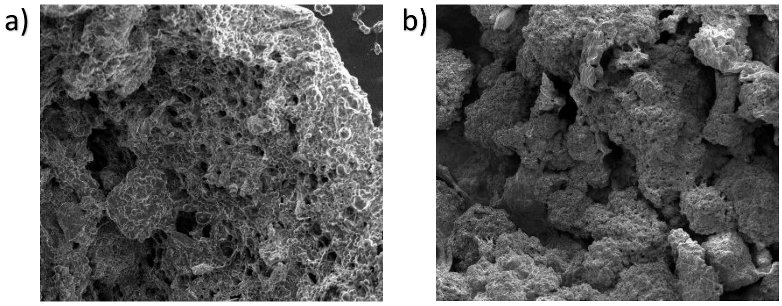


**Figure 3: Cross-section Images of (a) PVA/Alginate Polymeric Beads with 2.5 g of Banana Peel Waste; (b) PVA/Alginate Polymeric Beads without Banana Peel Waste**

**Mechanical Strength and Density of PVA/Alginate Polymeric Beads**

A further observation was carried out to determine the mechanical strength of polymeric beads with various amounts of banana peel waste impregnated into polymeric beads. The determination of mechanical strength using hydraulic impact resistance (Du, et al., 2020) aims to see the resistance of polymeric beads wall. Thus, the polymeric beads can be optimally used as adsorbent for copper(II) ion adsorption without wrecking or breaking down during the adsorption process.

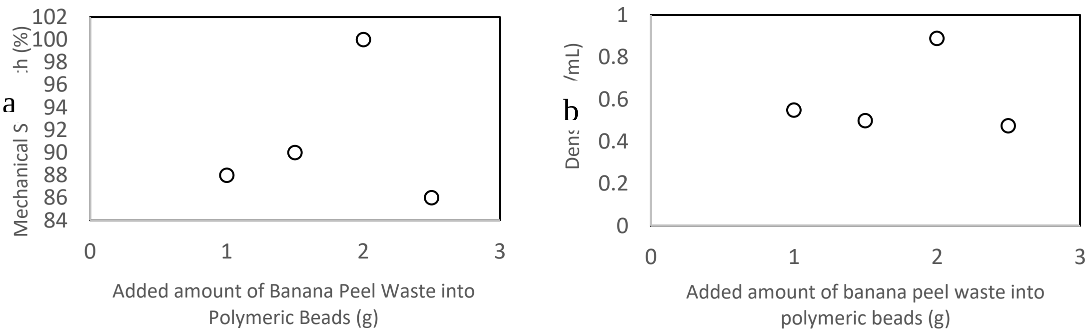


**Figure 4: Effect of the added amount of banana peel waste into PVA/Alginate polymeric beads on the mechanical strength of polymeric beads (a); and on the density of polymeric beads (b)**

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Figure 4 (a) is a mechanical strength graph of polymeric beads impregnated with various amounts of banana peel waste. The graph shows that the added amount of banana peel waste into polymeric beads affected the mechanical strength of polymeric beads. PVA/Alginate polymeric beads impregnated with 2 g of banana peel waste show the highest mechanical strength with the percentage of mechanical strength being 100%. It can be assumed that by increasing the amount of banana peel waste impregnated into the PVA/Alginate polymeric beads, the mechanical strength of the polymeric beads wall would be decreased.

The occurred phenomenon can be well-explained by the density of the PVA/Alginate polymeric beads impregnated with various amounts of banana peel waste as shown in Figure 4 (b). The graph shows that the highest density of PVA/Alginate polymeric beads is by impregnation with 2 g of banana peel waste. 2 g of banana peel waste impregnated into PVA/Alginate polymeric beads makes the polymeric beads more dense thus the mechanical strength of polymeric beads with 2 g of banana peel waste is more resistant when it tested using hydraulic impact resistance.

### pH Effect on Copper(II) Ion Adsorption using PVA/Alginate Polymeric Beads Impregnated with Banana Peel Waste

In the metal ion adsorption process, the pH of the solution plays an important role because of the precipitation of metal ions in the solution which might occur during the adsorption process. Therefore, it is important to determine the optimum working pH for copper(II) ion adsorption using PVA/Alginate polymeric beads impregnated with banana peel waste.

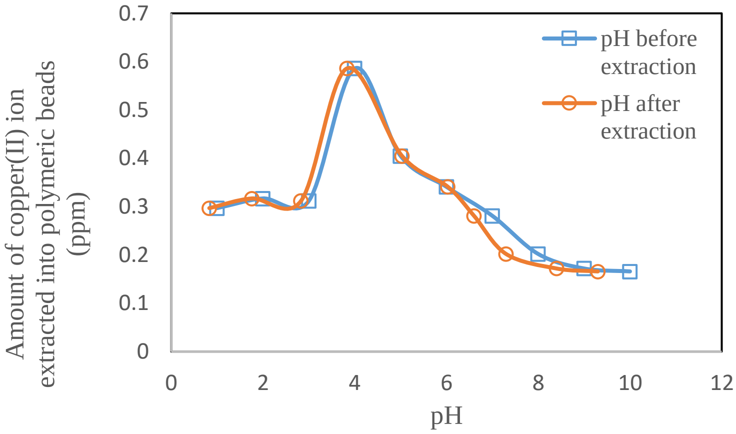


**Figure 5: pH Effect on Copper(II) Ion Adsorption using PVA/Alginate Polymeric Beads Impregnated with Banana Peel Waste**

The obtained result shows that the optimum working pH for copper(II) ion adsorption using PVA/Alginate polymeric beads impregnated with banana peel waste is at pH 4 with the amount of copper(II) ion extracted into polymeric beads is 1.383 mmol/g. The shifted pH to acidic pH after extraction shows that there was an ionic exchange between copper(II) ions from the solution with hydrogen ions from the adsorbent. The more acidic the shifted pH of the solution after extraction, the more active site on the adsorbent can be attached by the copper(II) ion. Thus, it leads to the increasing amount of copper(II) ion adsorbed into the polymeric beads. However, the shifted pH at pH 2 is wider than at pH 4 whereas the amount of copper(II) ion extracted into polymeric beads at pH 4 is higher than pH 2 by considering the higher concentration of hydrogen ion at pH 2 than at pH 4. It can be concluded that there was a competition between the hydrogen ion with the copper(II) ion in the solution, thus leading to the wider shifted pH to a more acidic condition.

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**Effect of Initial Concentration on Copper(II) Ion Adsorption using PVA/Alginate Polymeric Beads Impregnated with Banana Peel Waste**

As we know that the concentration solution will affect the amount of metal ion adsorbed into an adsorbent. An increasing amount of metal ion present in the solution, the increasing the amount of metal ion adsorbed and reached the equilibrium condition by considering that all of the active sites exist in the adsorbent would be occupied by the metal ion.

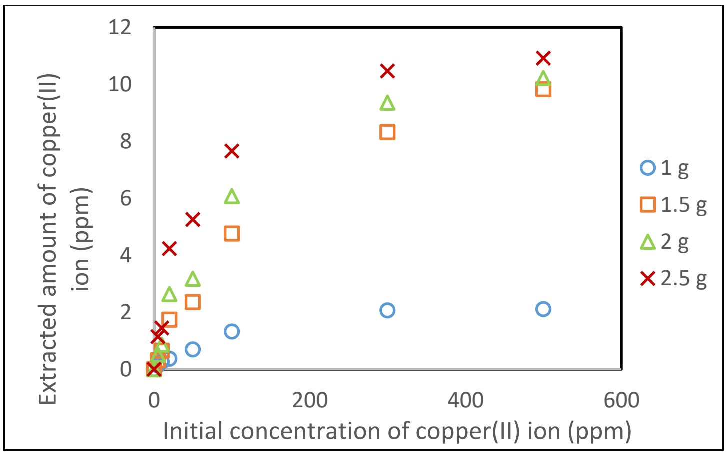


**Figure 6: Effect of Initial Concentration of Copper(II) Ion on Copper(II) Ion Adsorption using PVA/Alginate Polymeric Beads Impregnated with Banana Peel Waste**

Figure 6 is a representative of the extracted amount of copper(II) ion adsorbed into the PVA/Alginate polymeric beads with various initial concentrations of copper(II) ion in the solution. The graph shows that by increasing the initial concentration of copper(II) ion presence in the solution, the amount of copper(II) ion extracted into the polymeric beads would be increased and reached the equilibrium condition at a higher initial concentration of copper(II) ion in the solution. By increasing the amount of banana peel impregnated into polymeric beads, the amount of copper(II) ion extracted into polymeric beads would be increased and reached the equilibrium condition at the high initial concentration of copper(II) ion. Those data assume that almost all of the active sites that exist in the adsorbent have been occupied by copper(II) ions and reached the equilibrium condition with the initial concentration of copper(II) ions in the solution was 300 ppm.

**Conclusion**

Banana Peel waste has been successfully impregnated into PVA/Alginate polymeric beads. The amount of banana peel impregnated into polymeric beads affected the morphology of the obtained polymeric beads. The highest mechanical strength was shown by the polymeric beads with 2 g of banana peel waste. By considering the density of the obtained polymeric beads with 2 g of banana peel waste were denser than another amount of banana peel impregnated into polymeric beads. The polymeric beads were work-well at pH 4 with the amount of copper(II) ion extracted into the polymeric beads was 1.383 mmol/g. The increasing amount of initial concentration of copper(II) ion in the solution, the higher amount of copper(II) ion extracted into the polymeric beads and reached the equilibrium condition at a high initial concentration of copper(II) ion.

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