Adsorption of Pb(II) ion using pectin membrane

B Hastuti\textsuperscript{1} and S Hadi\textsuperscript{2}

\textsuperscript{1} Department of Chemistry Education, Faculty of Teacher Training and Education, Universitas Sebelas Maret
\textsuperscript{2} Department of Pharmacy, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret

E-mail: Budihastuti@staff.uns.ac.id

Abstract: Disposal of heavy metal ion into body waters may result in the disruption of aquatic biota ecosystem, thus needs to be overcome. In this study, a cellulose-based adsorbent membranes was developed as adsorbents of Pb ion. The membrane was prepared by mixing chitosan gel in 2,5\% acetic acid solution with pectin gel in water for 3 h. The solution then was printed out into a polypropylene container and dried. The membrane characterization was performed using FTIR for functional groups identification, and XRD and SEM for physical characteristic analysis. The results showed the stability and resistance of the pectin membrane in acidic environment. FTIR data confirmed main functional groups that participated in the adsorption process included carboxyl and hydrogen. The XRD data show that the adsorbent has an amorf phase. Furthermore, a solid structure of the adsorbent was showed by SEM data. Adsorption of pectin membranes to Pb (II) ions reaches a maximum at pH 4, an optimum time of 60 min with an adsorption capacity of 92.68\% and 92\%, respectively. Furthermore, the pectin membrane in adsorbing Pb (II) ions follows the Freundlich isotherm.

1. Introduction

Heavy metal contamination in aquatic ecosystems become a serious environmental problem, due to heavy metal toxicity and its accumulation in aquatic habitats [1]. Some of heavy metal are naturally occurring elements and are needed in small amounts as micronutrients by human body, while certain heavy metals have possibility to accumulated in the body and food chain, and bring a risk to human health.

Lead (Pb) is heavy metal which is associated with the damage to the central nervous system. Lead ions in the blood act as heavy metal poisons that affect almost all hemoglobin synthesis and porphyrin metabolism. Pb metal ion contaminants cause mental retardation [2]. Lead can also damage the kidneys, liver and reproductive system, basic cellular process and brain function[3]. Symptoms of poisoning are characterized by anemia, insomnia, headaches, dizziness, irritability, muscle weakness, hallucinations and kidney damage [4].

Several technologies were developed for heavy metal Pb removal and remediation from the aquatic environment [5]. Current treatment technology that is commonly used and is being developed is filtration, sedimentation, and adsorption. Compared to other methods, adsorption is one method that does not require high costs. Adsorption is the absorption of a substance (molecule or ion) on the surface of the adsorbent. The absorption mechanism can be divided into two, namely, physical absorption (physical absorption) and chemical absorption (chemisorption) [6].

One of the adsorbent biomaterials that has the potential to adsorb heavy metal ions is pectin[7]. Pectin is a polysaccharide that forms cell walls in plants [8]. Potential sources of pectin come from fruit and vegetables or waste. Pectin has a carboxyl group that can interact with heavy metal ions.
In this study, pectin will be synthesized into a membrane which is applied as an adsorbent for the metal ion Pb (II).

2. Experimental

2.1 Materials
All the primary reagents used were analytical grade purchased from Merck, Germany. Standard of Pb(II), NaOH, HNO₃, Acetic Acid 5%, Aquadest, Pectin from Surabaya.

2.2 Preparation of adsorbent.
0.2 g pectin was dispersed in 10 mL of acetic acid 5 % and then stirring until 1 h to form a gel. The pectin gel was then poured into a membrane casting and dried. After drying, the formed pectin was then characterized using FTIR to analyze functional groups, XRD to analyze membrane crystallinity, and SEM to analyze surface morphology.

2.3 Effect of acidity (pH) of the solution on metal adsorption
10 mg of pectin membrane was put into a glass containing 10 mL of 50 ppm Pb (II) solution which had pH variation of 2, 3, 4, 5, 6 and 7 with 0.1 M NaOH, 1 M NaOH and 0.1 M HNO₃. The mixture was stirred for 3 h at a speed of 40 rpm. Then the mixture was filtered. The filtrate and the blank solution were diluted with 0.1 M HNO₃ solution then analyzed by Atomic Absorption Spectroscopy (AAS).

2.4 Effect of contact time on metal adsorption
10 mg of pectin membrane was put into a glass containing 10 mL of 50 ppm Pb (II) solution which has been adjusted to the optimum pH then stirred with different time variations with variations in contact time of 15, 30, 45, 60, 75, 180, 360, 720 and 1440 min. Then the mixture was filtered, the filtrate was diluted with 0.1 M HNO₃ solution then analyzed with AAS.

2.5 Effect of solution concentration on metal adsorption
10 mg of pectin membrane was put into a glass containing 10 mL of Pb (II) solution with varying concentrations that have been adjusted to the optimum pH as the results of previous observations. The initial concentrations of Pb (II) solution used were 25, 50, 75, 100, 200, 300, 400 and 500 ppm. The mixture is stirred for 1 h. The mixture was filtered then the filtrate was diluted with 0.1 M HNO₃ solution then analyzed with AAS.

3. Results and discussions

3.1 FTIR characterization
Fourier Transform Infrared (FTIR) Spectroscopy were used to analyze the characteristic of the functional active group of the membrane. From figure 1, pectin membrane has three peak in the region 1600 cm⁻¹ and broad peak at in the region 3000-3700 cm⁻¹ indicating of the presence of hydrogen-bonded OH groups on 3464 cm⁻¹ and vibration of C=O on 1600 cm⁻¹. Spectra, 1300-1072 cm⁻¹ is C=O stretching and 1380 cm⁻¹ is C-H bending.
Figure 1. FTIR spectra of pectin membrane

3.2 XRD characterization

Pectin membrane was analyzed using X-Ray Diffraction (XRD) to understand the phase of the material. The XRD spectra of pectin membrane (Figure 2) show that the properties of pectin is amorphous. It can be seen characterized by the peak at $2\theta = 20^\circ$. The peak at $2\theta = 20^\circ$ shows that the membrane have an amorf phase.

Figure 2. XRD spectra of pectin membrane

3.3 SEM characterization

The surface morphology of pectin membrane was informed by Scanning Electron Microscope (SEM). SEM image shows that the pectin membrane have small and homogeneous pores (Figure 3). The surface and cross section of membrane showed in the 500X magnification. The cross-section image of pectin membrane shows the pores are smoother and smaller. This surface characteristic is an indication the membrane as an efficient absorbent for Pb(II) metal ion.

Figure 3. SEM image of pectin membrane
3.4 The Adsorption test

The effect of acidity (pH) of the solution on Pb(II) adsorption

The acidity of the solution is one important factor that determine the ability of metal ion adsorption. The pattern of adsorption of Pb (II) ions with variations in the pH of the solution is shown in figure 4. At pH 2, the adsorption of pectin membranes to Pb (II) ions has an absorption of 20%, and significantly increase and each maximum at pH 4, with absorption capacity of 90.45%. At pH 5 and higher, the adsorption tend to decrease.

![Figure 4](image)

**Figure 4.** The effect of pH on the pectin membrane adsorption

This maximum adsorption of the pectin membrane on pH range of 4 to 6 showing considerable potential the adsorbent for real applications, particularly for environmental water and industrial wastewater which tends to be having acidic pH.

3.5 The effect of contact time on Pb(II) adsorption

The profile of the effect of contact time on Pb (II) adsorption is shown in figure 5. Pb (II) adsorption increases rapidly as soon as it is contacted and reaching equilibrium after 60 min. By the time increasing, the adsorption tend to decreases. In the variation of the contacting of the pectin membrane against the Pb (II) ion, the optimum contact time was obtained at the contact time of 60 minutes with an absorption of 90.11%.
3.6 Effect of initial Pb (II) ion concentration
The results of the analysis of the ability of Pb (II) ion adsorption by Pectin adsorbents are shown in figure 6. The amount of metal ions adsorbed by the adsorbent is affected by the concentration of metal ions in solution. The optimum concentration of Pb (II) ions adsorbed on the pectin membrane has increased to a concentration of 300 ppm with an adsorption capacity of 209.57 mg/g. This indicates that the membrane pectin is able to adsorb maximum Pb (II) ions at a concentration of 300 ppm. Increasing the concentration of metal ions increases the number of adsorbent active sites which bind metal ions and decreases the free active sites. At the concentration of Pb (II) 400 ppm ion, the adsorption power of pectin membrane has decreased. This is because the surface of the pectin membrane has saturated with the adsorbed Pb (II) ions.

3.7 Isotherm adsorption of pectin membrane toward Pb (II) ions
Pb (II) ion adsorption on Pectin adsorbents follows the freundlich isotherm pattern. This shows that the mechanism of pectin membrane adsorption on Pb (II) ions occurs through physical absorption. This shows the interaction between the pectin membrane in adsorbing Pb (II) ions occurs by involving the surface of each adsorbent in a multilayer manner. The pattern of pectin membrane adsorption isotherm in adsorbing Pb (II) ions is shown in figure 7.
Figure 7. Freundlich adsorption isotherm of Pb(II) ion by pectin membrane.

4. Conclusion
Pectin membrane has the ability to absorb metal ion Pb(II), so it can be an alternative to heavy metal Pb bioremoval. Pectin membrane have hydroxyl and carboxyl active groups, and form a microporous membrane. Pectin membrane can absorb Pb(II) metal ion at optimum condition of pH 4 and contact time 60 minute with % adsorbed with % Pb adsorbed 92.68 and 90.11%, respectively. The pattern of isotherm adsorption follows the Freundlich isotherm.

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