The influence of solution pH on the absorption of heavy metals Cr (VI) by *Saccharomyces cerevisiae* biomass

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Abstract. In general, industries produce waste, which causes environmental pollution and is a danger to living things. Chromium heavy metal waste is one type of waste that has high toxicity that can lead to chronic poisoning, acute, and can cause cancer. Biological treatment is a choice to reduce the concentration of heavy metals in environmental media. This study uses a biosorption column that utilizes *Saccharomyces cerevisiae* bacteria using bacterial biomass made in a state of silence in a continuous column, then flowing Cr (VI) metal solution downflow with a constant flow rate. Laboratory analysis results show that the removal efficiency of Cr (VI) for the initial pH 3 solution is 44.74% - 77.84%, the pH 5 treatment is 7.52% - 30.54% and the pH 7 treatment is 5.80% - 11.40%. The highest removal efficiency occurred at pH 3 of 77.84%. The remaining metal concentrations in the barrel can reduce to 11.08 mg/L.

1. Introduction

Industrial development in the era of globalization has an essential role in human life but hurts the environment. In general, industries produce solid, liquid, or gas waste. Waste generated by industry will accumulate in the environment and can pollute the environment and be harmful to living things.

Chromium (Cr) heavy metal waste is one type of waste produced by several industries, such as the metal coating industry, the electronics industry, and the paint industry. This heavy metal waste has high toxicity which is determined by the valence of the ions, the greater the amount of valence of the ions, the higher the toxic level. Cr metal poisoning can cause lung cancer, chronic festering wounds, skin, and respiratory tract irritation [11].

Cr metal can enter naturally and non-naturally into the waters. Naturally, this metal enters water bodies due to the erosion factor in mineral rocks and the entry of dust in the air containing these metals into the waters through rainwater that carries the particulates into the water body. Meanwhile, non-natural, this metal enters the water due to human activities, in the form of industrial and household waste. In waters, various chemical processes occur, ranging from complexing to redox reactions. This chemical process also occurs in chromium metal and can result in the deposition or sedimentation of the metal at the bottom of the water [10].

The presence of heavy metals in the environment can be prevented and reduced by processing at sources of waste producers. Processing of heavy metal waste has been carried out so far is in physical
chemistry, among others, by oxidation and reduction, coagulation and sedimentation, filtration, ion exchange, reverse osmosis, electrochemical processing, and evaporation [4]. Biological treatment to reduce heavy metals is an alternative technology that has the potential to be developed because the cost required is not too significant and more environmentally friendly.

Biological treatment with biosorption is a type of treatment that utilizes microorganisms to eliminate/toxic metals in liquid waste. Bio sorption can be defined as the ability of inactive or dead biological material to absorb heavy metals passively quickly [1,3]. The biosorption process involves solid material (bio sorbent) and liquid (solvent) containing heavy metals to be absorbed. With the high-affinity power for sorbate, sorbate will be pulled and bound by different mechanisms [2].

Biosorbent has an important role in the biosorption process. The biosorption process will take place optimally if biosorbents have a high ability to absorb metals. The ability of metal absorption is strongly influenced by the characteristics of biosorbents. Strong biosorbents usually come from microorganisms. Strong biosorbents of some microorganisms are affected by the chemical makeup of dead microbial cells and their inactive cell metabolism [2]. The use of microorganisms as biosorbents has the advantages of low operational costs, high metal-binding efficiency, and capacity, minimum sludge produced, regeneration mechanism so that it can be reused, raw materials are widely available, easy to obtain, and do not require additional nutrients if using microbes that have been die [5,9]. One of the microbes that can be used as biosorbent to remove heavy metals is saccharomyces cerevisiae. Research on the use of these microbes as biosorbents and bioaccumulation of heavy metals has been carried out in previous studies. The use of Saccharomyces cerevisiae microorganisms as biosorbents is based on a very high surface area making it suitable as an absorbent cation [7,8].

The efficiency of absorption of heavy metals in the biosorption process is influenced by several factors, one of which is pH. The pH value affects the type of chemical interaction that occurs in the biosorption process between metal ions, functional groups on the surface of the biomass cell, and the degree of adsorbate ionization during the reaction. Previous research found that the absorption of uranium, zinc, and copper metals occurred in the pH range 4-5 [12]. Results Another study found that the kinetics and biosorption equilibrium of cadmium metal by Saccharomyces cerevisiae biomass of 35 mg/g cells at optimum conditions [6].

This study was designed to examine the effect of pH of the solution on the biosorption process of Cr (VI) metals using Saccharomyces cerevisiae. Knowing the optimum pH value in the biosorption process is expected to provide benefits in designing the Cr (VI) metal biosorption process on a larger scale, such as the application of biosorption to treat wastes containing Cr (VI) metals produced by industry.

2. Methodology

2.1. Research design
This research is a quantitative study carried out through laboratory-scale research experiments using the biosorption column. The biomass used to absorb Cr (IV) metal is the Saccharomyces cerevisiae biomass, which is placed in a continuous column. Furthermore, the Cr (VI) metal flows downflow with a constant flow rate through the IV line. The processing effluent is stored in bottles for testing samples on a CV-AAS device. Variations in reactor treatment and design presented in table 1.

| pH | Contact Time (minute) |
|----|-----------------------|
|    | 30 (T1)   | 60 (T2)   | 90 (T3)   | 120 (T4)  | 150 (T5)  | 180 (T6)  |
| 3  | P1T1  | P1T2  | P1T3  | P1T4  | P1T5  | P1T6  |
| 5  | P2T1  | P2T2  | P2T3  | P2T4  | P2T5  | P2T6  |
| 7  | P3T1  | P3T2  | P3T3  | P3T4  | P3T5  | P3T6  |
2.2. Preparation of *Saccharomyces cerevisiae* biosorbents

Stages of preparation of *Saccharomyces cerevisiae* biosorbents:

- **Culture preparation**
  The culture used is a commercial product before being used. The culture is allowed to stand on its side for 24 hours.

- **Medium preparation**
  The medium used is Potato dextrose broth, which is a medium for isolation, culture, and maintenance of fungi and yeast. 3.6 grams of the medium is suspended in 150 mL of distilled or deionized water. Then, the medium is heated to boiling for 1 minute so that it is mixed perfectly. Furthermore, sterilization was carried out in an autoclave for 2 hours with a temperature of 121°C, 1 atm pressure, then cooled at a temperature of about 45°C.

- **Manufacture of biosorbents**
  *Saccharomyces cerevisiae* is sterile inoculation into sterile and incubated PDB medium and shaker for 3 days at 150 rpm.

- **Biomass harvesting process**
  *Saccharomyces cerevisiae* 0.1 g biomass which has been shaker is then centrifuged at a speed of 3000 rpm for 15 minutes to separate the supernatant from the sorbent. Furthermore, the biosorbent from the centrifuge process is washed two times with sterile distilled water and then dried and turned off in an incubator for the next process.

2.3. Preparation of chromium artificial metal

Chromium artificial metal solution available in the laboratory has a concentration of 1000 mg/L, so it needs to be diluted to obtain the required metal chromium concentration of 50 mg/L for each experiment.

2.4. Testing the biosorption column

The biosorption column test is carried out using a chromatographic column, which is first washed to be in aseptic conditions before use. This column is cylindrical with an internal diameter of 1 cm and a height of 50 cm. The column is filled with 0.1 g *Saccharomyces cerevisiae* biosorbents. Then, the chromatography column is drained by a downflow and continuous Cr (VI) metal solution using an IV hose from the storage tank. The discharge in the chromatographic column flow process is adjusted by opening the valve to remain constant and stable. Effluent samples were taken according to a specified time interval and analyzed using the Cold Vapor-Atomic Absorption Spectrophotometry (CV-AAS) test. The following are the biosorption column design drawings used in this study to reduce Cr (VI) levels using *Saccharomyces cerevisiae*.

Chromium biosorption experiments in this study were tested at different pH solutions (3, 5, and 7) with a predetermined contact time (30, 60, 90, 120, 150, and 180 minutes). Cr (VI) metal concentrations in this study were uniform, which is equal to 50 ppm. In this study, temperature uniformity is also carried out due to the environmental adaptation of *Saccharomyces cerevisiae*, which is only at normal room temperature. The determination of the pH value used is based on several previous studies and adjusts to the living conditions of the biomass used. *Saccharomyces cerevisiae* is a fungus/yeast that can live well and move at low pH so that it becomes the foundation in determining the initial pH value of the solution in the biosorption process. In several studies related to the ability of *Saccharomyces cerevisiae* to absorb heavy metals, it is known that the absorption pH value is in the range of 3-6. Whereas for pH 7, it is a separate experiment from this study to see whether there is any absorption in neutral pH.

3. Results

Data from Cr (VI) metal biosorption testing by biomass *Saccharomyces cerevisiae* with a concentration of a solution of 50 mg / L presented in table 2 and figure 1, 2 and 3.
Table 2. Test data for the absorption of Cr (VI) metals at variations in the initial pH of the solution.

| Variation of treatment | Influent (mg/L) | Effluent (mg/L) | Removal Efficiency (%) |
|------------------------|-----------------|-----------------|------------------------|
| P1T1                   | 11.08           | 77.84           | 77.84                  |
| P1T2                   | 13.55           | 72.90           |                        |
| P1T3                   | 50              | 62.58           |                        |
| P1T4                   | 22.15           | 55.70           |                        |
| P1T5                   | 26.77           | 46.46           |                        |
| P1T6                   | 27.63           | 44.74           |                        |
| P2T1                   | 46.24           | 7.52            |                        |
| P2T2                   | 42.15           | 15.70           |                        |
| P2T3                   | 50              | 29.68           |                        |
| P2T4                   | 37.21           | 25.60           |                        |
| P2T5                   | 34.73           | 30.54           |                        |
| P2T6                   | 40.11           | 27.74           |                        |
| P3T1                   | 47.1            | 5.80            |                        |
| P3T2                   | 49.25           | 1.50            |                        |
| P3T3                   | 50              | 11.40           |                        |
| P3T4                   | 45.16           | 9.68            |                        |
| P3T5                   | 41.62           | 16.78           |                        |
| P3T6                   | 44.63           | 10.76           |                        |

The laboratory analysis results in the following table 1 show that the removal efficiency of Cr (VI) for the initial pH 3 solution was 44.74% - 77.84%, the pH 5 treatment was 7.52% - 30.54% and the pH 7 treatment was 5.80% - 11.40%. A metal allowance for Cr (VI) occurs at every pH variation, but the highest allowance occurs at pH 3. Detailed laboratory test results presented in table 2.

Figure 1. The removal efficiency of Cr (VI) at pH 3.
4. Discussion

The test results in table 2 and figure 1, 2 and 3 show that the initial pH of the solution has a significant effect on the surface of Saccharomyces cerevisiae biomass in the removal of heavy metal ions in the biosorption process of Cr (VI) metals. The higher the initial pH of the solution, the reduced level of the final concentration of Cr (VI) metal decreases. The degree of acidity (pH) is a major influence on the process of biosorption of heavy metals in solution because the pH value can influence the charge of active sites that exist in microorganisms. Besides, pH also affects the metals in the solution so that it will affect the interaction of metal ions with biosorbents [5].

In this study, it was seen that the pH range of solutions 3 and 5 was more effective in removing the Cr (VI) metal compared to pH 7. At pH 3, the Saccharomyces cerevisiae cell wall was very active and negatively charged so that metal absorption was effective. Absorption of heavy metals occurs due to the negative charge on Saccharomyces cerevisiae, which binds to the positive charge of the metal solution so that it can reduce the levels of metal ions Cr (VI), the remaining metal concentrations of Cr...
(VI) 11.08 mg/L. At pH 5, the removal efficiency of the metal Cr (VI) by *Saccharomyces cerevisiae* was 30.54%, with a final concentration of 34.73 mg/L solution. The ability to remove metal Cr (VI) at pH 5 is not as large as at pH 3 but still able to bind metal ions. This is because the *Saccharomyces cerevisiae* cell wall is still negatively charged so that interactions with the positively charged Cr (VI) metal ion occur. Whereas at pH 7, biosorption of Cr (VI) metal did not experience a significant decrease in concentration due to pH 7 being neutral. This results in *Saccharomyces cerevisiae* cell walls no longer able to bind heavy metals optimally, so the removal efficiency of Cr (VI) solution is only 16.78% with a final solution concentration of 41.62 mg/L. Besides, the absorption process at neutral pH becomes ineffective due to precipitation. The precipitation process starts at pH 6, so the optimum pH of the biosorption process occurs in the pH range of 3-5 [13].

The ability of *Saccharomyces cerevisiae* to absorb heavy metals is influenced by its cell wall components consisting of polysaccharides, proteins, lipids, chitin, and chitosan which have functional groups such as carboxylic, hydroxyl, sulphate, phosphate, phosphate, and amino, as well as monovalent and divalent ions in the form of functions. Na\(^+\), Mg\(^{2+}\), and Ca\(^{2+}\). In the biosorption process, the presence of this functional group causes *Saccharomyces cerevisiae* to play an effective role because the functional group in the cell wall is capable of binding to the metal ion Cr (VI). States that carboxyl and amino groups are the main groups that play a role in ion binding [8].

5. Conclusion
Absorption of Cr (VI) heavy metals by Biomass *Saccharomyces cerevisiae* using a biosorption column occurs when the initial pH of the solution is in the pH range 3. The efficiency of removing Cr (IV) metal concentrations in the pH range is 77.84%, with the lowest metal content remaining in the water sample as much as 11.08 mg/L.

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