Peat water treatment by adsorption using kaolin-based geopolymer

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Abstract. Geopolymers have zeolite-like chemical compositions, which has some characteristics such as wide surface area and excellent stability so that it can be used for adsorbents for peat water treatment. In this research, the kaolin based geopolymers were applied as an adsorbent for processing the peat water into clean water. The variable used in this research were adsorbent mass (1; 1.5; 2; and 2.5 g), and time (30; 60 and 90 minutes). The results indicated that the kaolin-based geopolymers were very efficient in removing color and organic content. The optimum condition was mass adsorbent of 1 g and time of 30 min, and the result was 100% for removing color and 98.77% for removing organic content.

1. Introduction

Peat water is surface water from peat soil with striking features. It has a brownish-red color, contains high organic matter, tastes sour, pH 2-5 and has a low hardness level [1]. Therefore, the quantity of peat water can be used as a water resource, but the quality of peat water cannot yet be used as drinking water. In order for peat water to be utilized, peat water must be treated first so that the parameters on peat water are in accordance with the requirements for clean water quality based on RI Minister of Health Regulation No. 416/MENKES/PER/IX/1990.

One characteristic of peat water is its high color content. The color of peat water is caused by high organic matter (humic acid), where a humic acid is an aromatic group [2]. Adsorption can remove various substances in water such as aromatic compounds, color content, and heavy metal compounds. Adsorption is the process of adsorption of a substance, on an adsorbent surface in the form of solids. There are many adsorbents that have been developed for treating peat water, such as using a composite of Fe₃O₄ and chitosan [3], bentonite and montmorillonite nanoparticles [4] and biochar [5].

Geopolymers have zeolite-like chemical compositions. Geopolymers are synthetic polymer materials that can be made from fly ash, kaolin, rice husks, and other materials contained silica and alumina. Geopolymers have been used in the innovation of making concrete to reduce CO₂ emissions [6] while Mužek et al. (2013) and Naghsh, M., & Shams, K. (2017) utilized geopolymer as an adsorbent in water treatment [7,8].

Mužek et al. (2013) used coal fly ash from power plants as a geopolymer base material [7]. However, the problem is fly ash from coal power plants is categorized as hazardous and toxic waste

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(PP No. 85 of 1999 concerning Management of Hazardous and Toxic Waste) thus that the use of fly ash is not appropriate for processing peat water into clean water. Therefore, in this study, kaolin was used as the base material for making geopolymer. This study aims to synthesize kaolin-based geopolymer for treating peat water. The effect of adsorbent loading on color and organic substance contents was studied.

2. Experimental

2.1. Materials

The raw material used in this study were peat water from Tapung, Kampar regency, and kaolin from Sigma Aldrich. Other materials used were sodium hydroxide (97 wt. % NaOH Merck), hydrochloric acid (HCl 37 wt. % Merck), sodium silicate (NaSiO$_3$, Merck) and distilled water.

2.1.2. Methods

2.1.2.1. Geopolymer preparation

The activator solution was made by mixing NaOH of 8 M solution with sodium silicate and stirred continuously until well mixed. Kaolin and activator solution was put in a container and stirred for 10-15 minutes at constant stirring speed. During the stirring process, distilled water was poured slowly until the mixture formed a paste. The paste obtained was put into the mold, then wrapped in aluminium foil, heated for 24 hours in an oven at a temperature of 85 °C. Geopolymer samples were removed from the oven and washed with distilled water until the pH was neutral. The adsorbent particle size of <0.074 mm was used in this study so that the geopolymer was crushed and sieved using No. 200 sieve. The obtained geopolymer then characterized by XRD and SEM.

2.1.2.2. Adsorption of peat water processes

Peat water samples were taken from Air Terbit Village, Tapung District, Kampar Regency. Procedure for taking peat water by SNI 6989.57: 2008 concerning the Method of Taking Surface Water. Samples were taken in upstream areas, Desa Air Terbit, Kampar. Then the initial organic content of the sample was analyzed. For maximum results, before the adsorption process, the pH of peat water is lowered by using HCl. The mass variation of the adsorbent used in this study is 1; 1.5; 2; and 2.5 g added to 200 ml of peat water. The mixture was stirred in a test jar with a speed of 240 rpm. Stirring time variations were 30, 60 and 90 seconds. The solution was then filtered and tested for the content of organic matter. Table 1 shows a comparison of several parameters of peat water with clean water quality standards.

| No | Parameters       | Unit     | Peat water | Clean Water Requirements  | Notes       |
|----|------------------|----------|------------|---------------------------|-------------|
| 1  | Color            | PtCo     | 425        | 50                        | Not suitable|
| 2  | Ph               | -        | 4.5        | 6.5-9.0                   | Not suitable|
| 3  | Organic matter   | mg/l KMNO$_4$ | 51.192   | 10                        | Not suitable|

*Based on RI Minister of Health Regulation No. 416 / MENKES / PER / 1990

3. Results and discussion

3.1. Characteristics of Kaolin-Based Geopolymer Adsorbents

The morphology of the geopolymer adsorbent used in this study was determined by SEM (Scanning Electron Micrographs). Figure 1 shows the SEM micrograph of the geopolymer adsorbent used in this study. It can be seen there are many unreacted particles which varied particle sizes up to 30 µm. It is indicating that not all kaolin used as the raw material polymerized into geopolymer. The geopolymers adsorbent also characterized using XRD. The diffractogram of the geopolymer adsorbent can be seen in Figure 2. The peaks pattern in the diffractogram obtained is similar to the peak patterns of seven days age kaolin based geopolymer from the reference. The peaks patterns in the diffractogram corresponding to a zeolite X patterns [8] and there are kaolinite, quartz, and muscovite. It is indicated
that kaolin minerals are still in this geopolymer adsorbent. This is in accordance with the result of SEM characterization that the geopolymer adsorbent made in this study was not perfect. There was part of kaolin not polymerized. Even though the polymerization was incomplete, for catalyst and adsorption application, the incomplete polymerization provides a more active site from the crystalline structure from unreacted kaolin and also zeolite like structure.

![SEM micrograph of kaolin-based geopolymer with magnifications of 3000x](image1)

![The XRD diffraction of solid obtained](image2)

### 3.2. Peat Water Characteristic

This research was carried out in a laboratory using peat water with an organic content of 51.19 mg/l, the color was brown with an intensity of 425 PtCo and a pH of 4.5. The three parameters were not yet in accordance with the standards set by the government through the Minister of Health Regulation No.416/MENKES/PER/IX/1990 concerning drinking water and clean water standards.

### 3.3. Result of Peat Water Treatment with Kaolin-Based Geopolymer Adsorption

#### 3.3.1. Effect of pH on peat water adsorption

The effect of pH on decreasing the color intensity and organic matter content was determined by carrying out the adsorption at pH 1.5; 3; and 4.5. The pH was lowered by using HCl. Figure 3 shows the effect of pH on decreasing organic matter and color. It can be seen that organic matter and color
decreased when pH was lowered from the initial pH of 4.5. The highest removal was 100% for color and 62.96% for the organic matter at pH 1.5. From this finding, it can be concluded that the lower the pH, the higher the removal of organic matter. The higher removal occurs because, at low pH, humic acid has a spherical structure whereas at high pH the structure is rather linear, so if the pH has increased the size of the molecule humic acid will increase, and this causes the adsorption capacity to decrease [9].

Figure 3. The Effect of pH on color reduction efficiency and Organic Substances

3.3.2. Effect of adsorbent mass and time on peat water adsorption

The result of color and organic matter reduction by variation of mass of adsorbent are shown in Figures 4 and 5. The sample after processing look clear and this is in accordance with the results of the color test which drops from 425 PtCo to 0 PtCo, the highest color reduction efficiency was obtained at 1 g of adsorbent the result was 100% of color can be reduced. The efficiency of decreasing levels of organic matter was also proportional to the decrease in color. The highest efficiency of decreasing organic matter levels was also at 1 g mass of adsorbent, the organic matter decrease from 51.192 mg/l to 0.63 mg/l it is mean that the geopolymers can adsorb 99.87% of organic matter. From Figures 4 and 5, it can be seen that the mass of the adsorbent is inversely proportional to the efficiency of color and organic matter reduction.

Figure 4. Effect of adsorbent mass on color reduction

Figure 5. Effect of adsorbent mass on organic substances reduction
4. Conclusion
The kaolin-based geopolymer can be used effectively to reduce the color and organic matter content in peat water. The highest reduction of organic matter and color of peat water was obtained at pH of 1.5; mass geopolymer of 1 g for 200 cm$^3$ peat water and time of 30 seconds. The results kaolin based-geopolymer obtained can adsorbs 100% of color and 98.77% of organic matter. The high efficiency of color and organic matter adsorption in this study proves that this method is feasible to be used as an alternative for processing peat water.

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