Characterization of Activated Carbon Prepare from Low-rank Coal of East Kalimantan by using Acid and Base Activation

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Abstract: Indonesia is one of the countries that has large coal reserves in the world. Low rank coal in Indonesia reached 28.4% of coal reserves, 67,198,300,021 tons/year of low-rank coal production in East Kalimantan. Despite their vast reserves, low-rank coals are considered undesirable because has less economic value; their high moisture content, entails high transportation costs, potential safety hazards in transportation and storage and the low thermal efficiency obtained in combustion of such coals. Besides improving its economic and usage values, processing low-rank coal into activated carbon becomes alternative way of utilization of abundant amount of low-rank coal. The aim of this research is to determine the characteristics of activated carbon produced from low rank coal of East Kalimantan by using acid and base activation with different activators : HCl, H_3PO_4 and NaOH. Low rank coal which has been prepared -100 +120 mesh is carbonized at 600^0C for 3 h, then after cold it was activated using 2.5 M concentration of HCl, H_3PO_4 and NaOH for 8 h. Furthermore proximate analysis were used to investigate the characteristics of activated carbon produced such as moisture content, ash content, volatile matter and fixed carbon. Meanwhile, the adsorption capacity of activated carbon is determined through the iodine adsorption number. The quality requirements for activated carbon refers to Indonesian National Standard (SNI 06-3730-1995). The best results were obtained by using HCl with activated carbon characteristics such as a moisture content, ash content, volatile matter, fixed carbon and iodine absorption number respectively as follows 5.23%, 11.72%, 8.85%, 74.2% and 660.40 mg/g. Activated carbon is one of the mostly widely used adsorbents. In the treatment of wastewater, it is usually employed for purification, decolorization and the removal of toxic heavy metal ions and organic pollutants.

1 INTRODUCTION

Coal was formed by the decomposition of plant matter , and it is a complex substance that can be found in many forms. Coal is divided into four classes: lignite/low-rank coal, sub-bituminous, bituminous and anthracite. Low-rank coal in Indonesia reached 28.4% of coal reserves, 67,198,300,021 tons/year of low-rank coal production in East Kalimantan (Demirbas, 2007). Activated carbon is mainly composed of carbonaceous material with various porous structures and it is one of the mostly widely used adsorbents (Bilal, 2016). Activated carbons have been widely employed in water and wastewater treatment processes for removing organic contaminants, because they generally have large adsorption capacity (Tsai, 2001). This activated carbon has a specific affinity for non-polar compounds, such as organics (Dong Su Kim, 2004). Activated carbon can be produced from different sources, such as lignocellulosic materials, coal, bagasse ash, asphalt and oil, waste tyre rubber, activated sludge and others (Shawabkeh and Ghamdi, 2014). Coal has the potenti al as a raw material to produce activated carbon because it has a high carbon content (Speight, 1994).

The production process of activated carbon mainly consists of three steps: dehydration, carbonization, and activation. Dehydration is a drying process to remove moisture content from the raw material. During carbonization, organics contained in the raw material are converted into primary carbon, which is a mixture of amorphous, crystalline carbon, tar, and ash. Activation is the main step in the

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whole process and is usually carried out in two ways: physical and chemical activation. Physical activation usually involves the carbonization of pre-cursor followed by the gasification of the resulting char or direct CO_2/steam activation of the starting material. Chemical activation involves the impregnation of the given precursor with activation agent such as phosphoric acid (H_3PO_4), chloric acid (HCl), nitrit acid (HNO_3), zinc chloride ($ZnCl_2$), and alkaline metal compounds (Dong-Su Kim, 2004). The adsorption performance of activated carbon, to a large extent, depends on the choice of activators (Fen Li, Bo Yan and Tao Lei, 2014).

The adsorption capacity of activated carbon is very important because this property determines how much of the substance can be absorbed per gram of carbon (Demirbas, 2007). This capacity is related to the pore structure and chemical nature of the carbon surface in connection with preparation conditions (Pehlivan and Cetin, 2008). The quality requirements for activated carbon refers to Indonesian National Standard (SNI 06-3730-1995) with max.15% moisture content, max.10% ash content, max. 25% volatile matter, min. 65% fixed carbon and min. 750 mg/g iodine absorption number (Departemen Perindustrian and Perdagangan, 2003).

Lots of research has been reported on the preparation of activated carbon from different sources and on the effects of diferrent preparation condition on the characteristics of the activated carbon. Research conducted by Maulana et.all (2017) "Activation Process of Candlenut Shell Use Different Activators (H_3PO_4, $CaCl_2$, NaOH) and Concentration" The best result were obtained at 15% concentration of NaOH, produce activated carbon with characteristics of moisture content, ash content, volatile matter, fixed carbon and iodine absorption number respectively as follows 5.55%, 7.65%, 65.54%, 27.80% and 663.82 mg/g. Another study was making of activated carbon from sub-bituminous coal with chemical activation using H_3PO_4 and combination of H_3PO_4-NH_4HCO_3 activators. Sub-bituminous is carbonized at 600ºC for 3 h, continued by chemical activation for 8 h and drying process at 600ºC for 2 h. The best result were obtained on the concentration H_3PO_4-NH_4HCO_3 2.5 M with moisture content of 7.4%, ash content of 10%, volatile matter of 39.1%, fixed carbon of 43.5 % and iodine absorption number of 1238.554 mg/g (Kusdarini and Ghafarunnisa, 2017).

The aim of this research is to determine the characteristics of activated carbon produced from low rank coal of East Kalimantan by using acid and base activation with different activators such as HCl, H_3PO_4 and NaOH.

2 METHODOLOGY

Low rank coal which has been prepared -100 +120 mesh is carbonized at 600^0C for 3 h, then after cold it was activated using 2.5 M concentration of HCl, H_3PO_4 and NaOH for 8 h. Furthermore, an analysis of activated carbon refers to Indonesian National Standard SNI 06-3730-1995 was carried out including moisture content, ash content, volatile matter, fixed carbon and iodine absorption number. Coal to be processed into activated carbon is determined by parameters of moisture content, ash content, volatile matter, fixed carbon, iodine absorption number and calorific value respectively as follows 37.86%, 5.53%, 25.06%, 31.55%, 215.75 mg/g and 3665 cal/g.

3 RESULTS AND DISCUSSION

Table 1 summarizes the results of activation low-rank coal using acid and base activators.

Table 1: Characteristics of Activated Carbon after Activation Low-Rank Coal.

Parameter, %	Activators			SNI Standard
	Acid		Base	
	HCl	H_3PO_4	NaOH	
Moist. Content	5.23	3.42	4.67	Max. 15%
Ash Content	11.72	13.25	13.64	Max. 10%
Volatile Matter	8.85	10.13	10.61	Max. 25%
Fixed Carbon	74.20	73.20	71.08	Min. 65%
Iodine Adsorption Number, mg/g	660.4	469.53	479.11	Min. 750

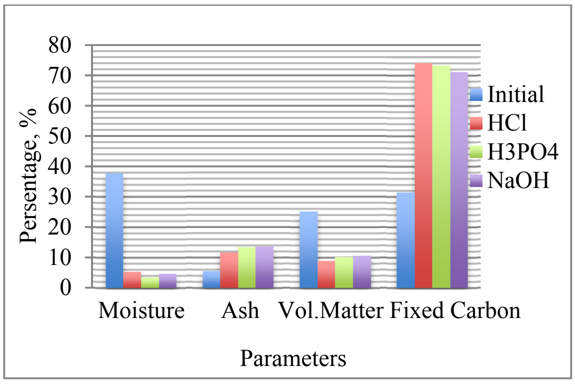

Figure 1: Characteristic of Low Rank Coal at Initial Condition and After the Activation Process with Different Activators.

In Figure 1 can be seen that moisture content of low rank coal has decreased from 37.86% to 3.42 – 5.23%. The lowest moisture content produced by coal activated by H_3PO_4 is 3.42% while the highest moisture content produced by coal activated by HCl is 5.23%. Acid activators cause complex damage to oxygen during the activation process so that the moisture content in activated carbon is less than base activators (Erawati and Fernando, 2018). But it does not happen to HCl activators because the pH produced is so small that it requires more water in the neutralization process. This causes activated carbon to absorb more water. Refers to Indonesian National Standard (SNI 06-3730-1995), allowable moisture content max. of 15%.

The ash content of the activated carbon has increased from 5.53% to 11.72 – 13.64%. The increase in ash content was due to the carbonization process at high temperatures cause the oxidation of most volatile substances including carbon. Whereas ash is not oxidized because it is not a volatile substance. Based on Figure 1, the use of acid activators produces lower ash content compared to alkaline/base activators. This is because the acid activators of HCl and H_3PO_4 bind together with the alkaline elements in activated carbon and form salts that dissolve easily in water. Conversely, the base activators such as NaOH, contain the mineral element (sodium, Na) will be absorbed in the pores of activated carbon thereby increasing ash content in activated carbon (Rahim and Indriyani, 2010). Based on Indonesian National Standar (SNI 06-3730-1995), allowable ash content max. of 10%.

The use of activators in the activation process is able to reduce component of non-carbon compounds found on the surface of activated carbon and enlarge the surface pores of activated carbon (Maulina and Iriansyah, 2018). Figure 1 shows acid and base activators able to degrade organic matter that is present on the surface of carbon and also release volatile materials. The lowest volatile matter produced by coal activated by HCl is 8.85% while the highest volatile matter produced by coal activated by NaOH is 10.61%. Refers to Indonesian National Standard (SNI 06-3730-1995), max. 25% volatile matter allowed.

The fixed carbon of low-rank coal was 31.55%, it has increased after the activation process to 71.08 – 74.2%. This can be seen in Figure 1. The increased in fixed carbon was due to decrease in moisture content and volatile matter of activated carbon. Refers to Indonesian National Standard (SNI 06-3730-1995), allowable fixed carbon of min. 65%.

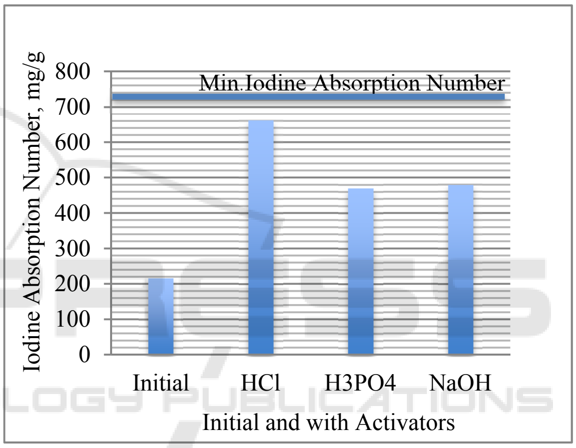

Figure 2: Iodine Absorption Number of Low-Rank Coal at Initial Condition and After the Activation Process with Different Activators.

The iodine adsorption number reflected the adsorption per-formance of activated carbon, as shown in Figure 2. It tends to increase from 215.75 mg/g to 469.53 mg/g – 660.40 mg/g. The iodine absorption number of H_3PO_4 and NaOH activators is lower than HCl because some of minerals element such as sodium (Na) in NaOH is absorbed in the pores of activated carbon. It causes the micropore structure that has been formed to be covered again by the Na element, thereby reducing the absorption capacity of activated carbon. The highest iodine absorption number were obtained by using HCl activators was 660.40 mg/g. Refers to Indonesian National Standard (SNI 06-3730-1995), allowable iodine adsorption number of min.750 mg/g. The iodine absorption number of activated carbon in this research still below the standards referred to.

4 CONCLUSIONS

1. Activation of low-rank coal of East Kalimantan was evaluated by taking different activators. The best result were obtained by using HCl with activated carbon characteristics such as a moisture content, ash content, volatile matter, fixed carbon and iodine absorption number respectively as follows 5.23%, 11.72%, 8.85%, 74.2% and 660.40 mg/g.
2. Ash content and iodine absorption number still below the standards referred to Indonesian National Standard (SNI 06-3730-1995).

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