

# Adsorption and Pore of Physical-Chemical Activated Coconut Shell Charcoal Carbon

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**Abstract.** The adsorption of activated carbon of coconut shell charcoal on heavy metals (Cu and Fe) of the wastewater and its relation with the carbon pore structure was investigated. The coconut shell was pyrolyzed in kiln at temperature about 75 - 150 °C for about 6 hours to produce charcoal and then sieved into millimeter sized granule particles. Chemical activation was done by immersing the charcoal into chemical solution of KOH, NaOH, HCl and H<sub>3</sub>PO<sub>4</sub>, with various concentration. The activation was followed by physical activation using horizontal furnace at 400°C for 1 hours in argon gas environment with flow rate of 200 kg/m<sup>3</sup>. The surface morphology of activated carbon were characterized by using Scanning Electron Microscopy (SEM). Wastewater was made by dissolving CuSO<sub>4</sub>.5H<sub>2</sub>O and FeSO<sub>4</sub>.7H<sub>2</sub>O into aquades. The metal adsorption was analyzed by using Atomic Absorption Spectroscopy (AAS). The result shows that in general, the increase of chemical concentration cause the increase of pore number of activated carbon due to an excessive chemical attack and lead the increase of adsorption. However it tend to decrease as further increasing in chemical activator concentration due to carbon collapsing. In general, the adsorption of Cu and Fe metal from wastewater by activated carbon increased as the activator concentration was increased.

## 1. Introduction

Water contamination from industrial wastewater due to toxic heavy metals content is one of the severe environmental problems [1]. Toxic heavy metals such as Fe and Cu are the main water pollutant due to undegradeable biologically into environment. However, agricultural waste by product can be used as an absorbent [2]. Coconut shell charcoal, as an agricultural waste, with elements content of Carbon (45.03%), Hydrogen (6.94%), Oxygen (47.47%) and ash (0.56%) as an agriculture waste product has been used as effective and inexpensive adsorbent of heavy metal wastewater. Furthermore, the production of activated coconut shell charcoal carbon consume less electrical energy, human toxicity and global warming thus the process is friendly to environment [3]. Naturally, the chemical composition of coconut shell consists of lignin (29.35%), cellulose (24.20%), hemicellulose & others (38.56%), moisture (7.7-3%) and ash (0.68%) [4]. The shell carbon content increases up to 76.32 % as the shell was pyrolyzed into charcoal [5]. The carbon structure of cocout shell charcoal has high porosity and large surface area and this properties are important in adsorption process.

The coconut shell charcoal can be activated by physical and or chemical activation. The chemical reagent The chemical activation was performed by impregnating the charcoal into activating reagent such as KOH, NaOH, HCl and H<sub>3</sub>PO<sub>4</sub> [6]. The reagents were reactive in opening the pore wider. The



chemical activation has advantages than physical activation due to its higher yield lower activation temperature. The process can reduce drastically empty space and lower weight loss thus increase packing density and proportion of mesopores [7]. The physical activation can tailor the pore size distribution more accurately but lower packing density. However the process is more friendly to environment since it use no any toxic chemical solution. The granular activated carbon can be used as excellent alternative, effective and inexpensive absorbent to remove high amounts of heavy metal such as Fe and Cu from waste water [8, 9].

The objective of this paper is to investigate the adsorption of activated coconut shell charcoal carbon on heavy metal of Fe and Cu of waste water. The pore and surface morphology of activated carbon were also discussed.

## 2. Experiment

The coconut shell as raw material was collected from natural waste of local markets in Jakarta. The shell was cleaned from coir and then dried under sun light for about three days. The coconut shell charcoal was produced by pyrolysing 100 kg shell in the kiln at temperature about 75-150 °C for about 6 hours. After the process, the coconut shell was converted into coconut shell charcoal. The charcoal then was cleaned by using aquades and dried by using furnace at temperature of 120 °C for about 12 hours. After that, the charcoal was sieved by using mortar to form milimeter size granule and cleaned again by using aquades before cleaned by using ultrasonic cleaner in 96% alcohol at room temperature for 30 minutes and dried by using hot plate for 60 minutes.

The chemical activation was performed by immersing the charcoal for 24 hours into KOH solution with various concentration of 30, 40, 50 and 60% ; NaOH solution with various concentration of 1%, 2%, 4%, 7% and 11%; HCl and H<sub>3</sub>PO<sub>4</sub> solutions with both various concentration of 2%, 4% and 6%. After that the charcoal then washed by using aquades and dried by using hot plate for 3 hours. All the charcoal samples was then physically activated by using horizontal furnace at fixed temperature of 400 °C in argon gas environment with its pressure of 200 kg/m<sup>3</sup> for an hour.

The surface morphology and pore structure of activated carbon was characterized by using Scanning Electron Microscopy (SEM) analysis (Jeol, JED-2300). Batch (static) and dynamic experiments were conducted at room temperature to study the adsorption performance. Two wastewater containing 5 mg/lit CuSO<sub>4</sub>.5H<sub>2</sub>O and FeSO<sub>4</sub>.7H<sub>2</sub>O were used for the adsorption performance of 3 gram sample of activated carbon in 25 ml of the wastewater. In batch experiment The adsorption of activated carbon on Fe and Cu wastewater was analyzed by using Atomic Adsorption Spectroscopy (AAS).

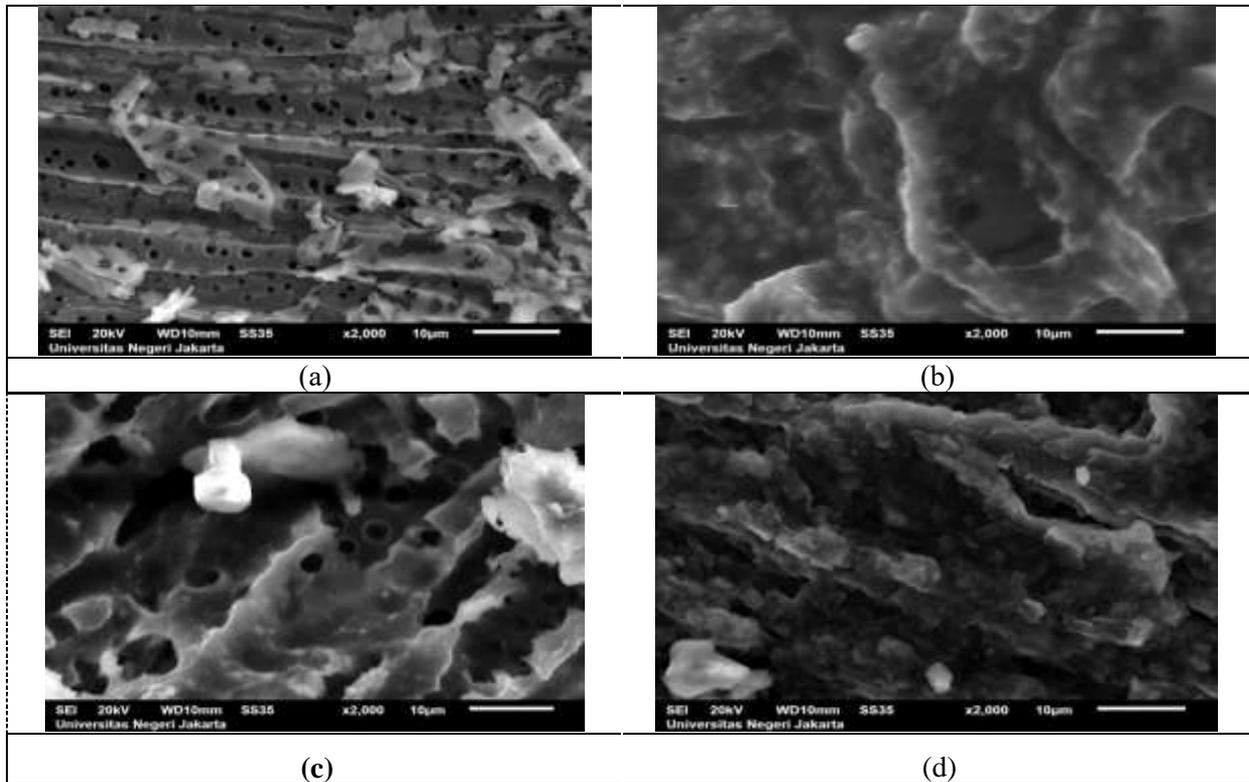
## 3. Results and discussion

### 3.1. Pore and surface morphology of activated carbon

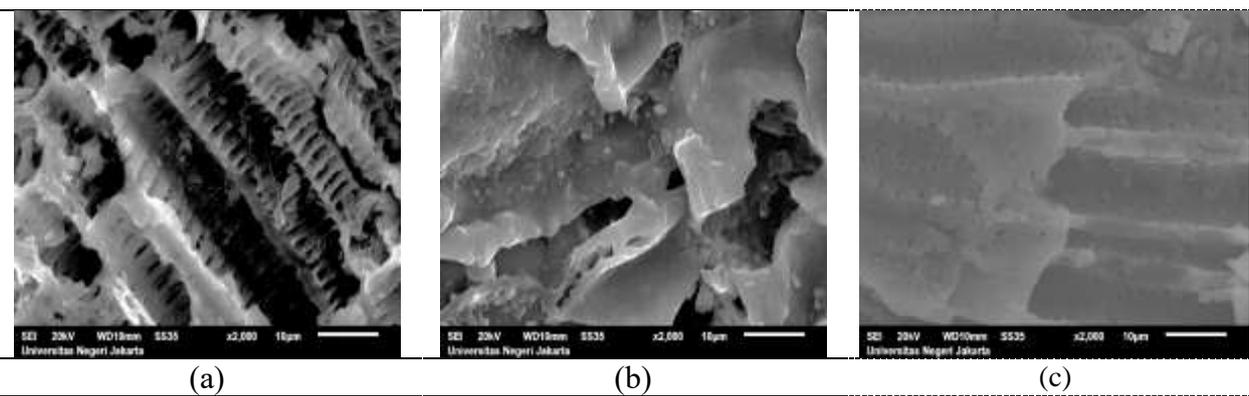
The pore and surface morphology of activated carbon at various KOH and NaOH activator concentration are showed in Figure 2 and Figure 3, respectively. While, the pore and surface morphology of activated carbon H<sub>3</sub>PO<sub>4</sub> activator is showed in Figure 4. It shows that in general, the pores are distributed on the carbon surface and its distribution is influenced by chemical agent concentration.

It shows that the chemical agent attack the charcoal carbon surface and develop supplemental pores and internal surface. The process leads to the increase of the pore number and size [5]. The agent also can react with hydrocarbon and develop some pores in microcrystalline carbon of charcoal [10]. However, the pore number then decrease at further increasing chemical agent concentration due to the incipient carbon collapsing after excessive chemical agent attack [11]. The pore size increase as the chemical activator concentration is increased lead the decrease of micropore number and increase of the mesopore and macropore numbers. At the same time, the distribution of pore size become narrower and wider [12].

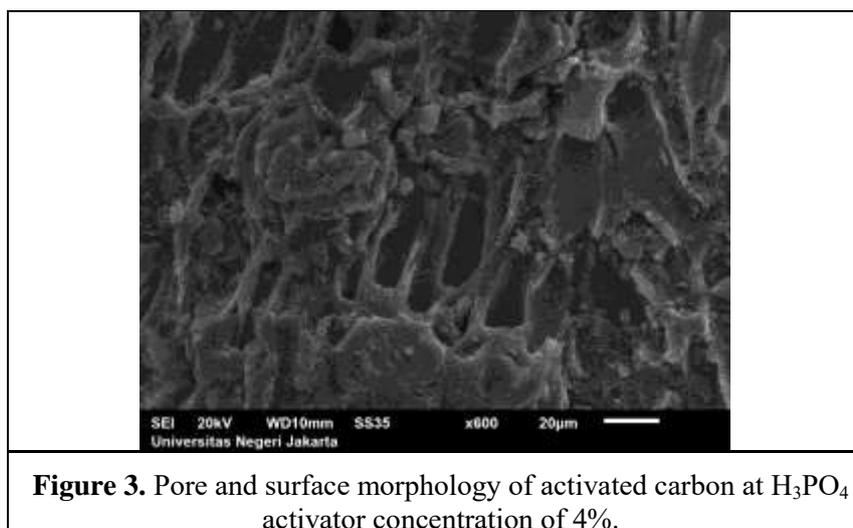
During activation process the residual organic molecules such as hydrocarbon was dehydrated by the chemical activator and was prevented to be deposited on the carbon surface. The hydrocarbon was removed during the physical activation at high temperature and inert gas condition [11,13]. The chemical activator also inhibit the formation of volatile matter, tar and other liquid that might deposit in the pore [14].



**Figure 1.** Pore and surface morphology of activated carbon at various KOH activator concentration of (a) 30%, (b) 40%, (c) 50% and (d) 60%.



**Figure 2.** Pore and surface morphology of activated carbon at NaOH activator concentration of (c) 4%, (d) 7% and (e) 11%.



### 3.2. Adsorption of activated carbon

The experimental results on the heavy metal adsorption of activated carbon are shown in following tables. Generally, the adsorption increase as the chemical activator concentration is increased.

**Table 1.** AAS analysis for adsorption of Cu and Fe metals by samples activated at various KOH concentration. Initial Cu and Fe concentration is 2.4512 ppm and 2.3613 ppm, respectively.

KOH concentration (%)	Cu concentration (ppm)	Fe concentration (ppm)
30	0.4703	0.6809
40	0.4615	0.5831
50	0.4027	0.704
60	0.6626	0.5839

**Table 2.** AAS analysis for adsorption of Cu and Fe metals by samples activated at various NaOH concentration. Initial Cu and Fe concentration is 2.4512 ppm and 2.3613 ppm, respectively.

NaOH concentration (%)	Cu concentration (ppm)	Fe concentration (ppm)
1	0.4687	1.8032
2	0.5212	2.124
4	0.5316	1.6942
7	0.5399	1.6405
11	0.4677	1.8770

**Table 3.** AAS analysis for adsorption of Cu metals by samples activated at various HCl concentration. Initial Cu concentration is 2.4512 ppm.

HCl concentration (M)	Cu concentration (ppm)
2	0.2862
4	0.0786
6	0.0276

**Table 4.** AAS analysis for adsorption of Cu metals by samples activated at various H<sub>3</sub>PO<sub>4</sub> concentration. Initial Cu concentration is 2.4512 ppm.

H <sub>3</sub> PO <sub>4</sub> concentration (M)	Cu concentration (ppm)
2	1.0488
4	1.386
6	1.6127

The adsorption process depend on the cation charge density and diameter of hydrated cation where the large diameter of ion has minimum adsorption [8]. Its known that the cation charge density of Fe<sup>+2</sup> and Cu<sup>+2</sup> is the same but both ions have different atomic radius which radius of Cu<sup>+2</sup> is larger than that of Fe. However, since the pore size of activated carbon in this investigation is about 50 – 125 nm that bigger than metal ion radius size thus both Fe and Cu metal ions should be easy to be penetrated into the pore. In this experimental results, however, the efficiency of Cu heavy metal adsorption is higher than Fe.

The driving force of metal adsorption mechanism onto the activated carbon depend on the solubility and affinity of adsorbate [15]. It may be due to the bonding type between metal ion and activated carbon. In general the adsorption capacity of Cu is higher than Fe, thus it might be that the Fe ion is easier to be deposited causes the adsorption process is not completely.

#### 4. Conclusion

The physical-chemical activation on coconut shell charcoal can evolute and modify the pore structure and eventually improve its adsorption capacity on the heavy metal such as Fe and Cu. In general, the adsorption of activated carbon on Cu heavy metal is higher than that of Fe heav metal.

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