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# Adsorption Kinetics Of Phenol In Aqueous Solution Using Local Charcoal Activated Carbon Products

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**The research of the adsorption kinetics of phenol in aqueous solution was studied by measuring the concentrations of remaining phenol in the solution as a function of time (t) and the parameters of the operating temperature (T), the particle diameter of activated carbon (d) and the ratio of the mass of the adsorbent to the mass solution (r). This research used the adsorption method by using local charcoal activated carbon products. The study was conducted by measuring the adsorption velocity (the ratio between the concentration of adsorbent before and after the adsorption operation took place) as a function of time, by varying the operating temperature, grain size, and the ratio of the mass of the adsorbent per mass of solution. In this research, the method used to evaluate constants value in the empirical rate expression is the graphical method. The results of the research show this adsorption method is one way of handling the waste which is quite easy and economical.**

**KEYWORDS**

Industry, Adsorption kinetics, Phenol, Charcoal, Local charcoal, Activated carbon

## 1. INTRODUCTION

The rapid industrial development over the past five decades has been widely recognized problem that created more job opportunities and also generated more revenue for a country. However, it is also causing harm to the environment the impact of which is caused by pollution in water, soil and air which in turn can disturb human health [1,2,3,4,5]. Several of the cities in Indonesia have reported that air pollution especially particles has an impact on the environment. Industrialization one of the contributing sources of pollutants [6,7]. Most of the industry is paying more attention to the amount of benefits received from industrial processes, rather than issuing fees for processing waste industry results leading to a small number of industries to manipulate reports. Every industry needs to handle phenol levels so that the waste does not exceed a specified threshold set by Government, because the levels of phenol in water are very influential in determining water quality [8]. One of the more effective and efficient way which can be used as an alternative method to control phenol waste levels released from industry is through the process of adsorption [9,10,11].

On the research of the adsorption method is used by using local charcoal activated carbon. This method is one way of handling the waste which is quite easy and economical. Activated carbon is carbon that has the adsorption against waste gas, liquid and colloidal [12,13]. Some research earlier just learn how to make activated carbon from various types of materials found in nature with the diverse methods of activation and then test the ability of certain pollutants against adsorption. Published research shows that the interaction of biochar adsorption on heavy metals involves electrostatic attraction, transition, physical adsorption, complexation, precipitation and multiple combinations force [14,15,16,17,18]. This research, using activated carbon products has been available in the market and see if it is just as effective and efficient in the waste adsorb by calculating the kinetics adsorption. This adsorption kinetics data is also very necessary to design the process of adsorption on an industrial scale, This research is expected can be information that needed the industry.

## 2. MATERIAL AND METHOD

The materials used in this research are phenol solution, activated carbon and distilled water. The activated carbon granules used are local charcoal activated carbon with specifications: density 2267 kg/m$^3$, bulk density 450 kg/m$^3$, grain diameter 0.5-2 mm (8-30 mesh) and specific surface area 477 m$^2$/gm.

### 2.1 Stages of adsorption parameters operating temperature with local charcoal activated carbon

Phenol solution 100 ppm put in as many as 250 mL Erlenmeyer flask 100 mL and then put in a shaker water bath which has been set at level 303K. Activated carbon type as much as 20 gm is inserted into an Erlenmeyer flask. Started shaking out with shaker water bath is turned on for 60 min. Sample take for analysis of residual phenol levels every 5 min. Then, repeated the same steps for the temperature of the water bath shaker 323K, 343K, and 363K.

### 2.2 Stage of sampling

Samples take every 5 min as much as 5 mL by pipetting use 5 mL measuring pipette and inserted into the sample bottle. Then the samples that have been taken in order to be filtered using filter paper powder activated carbon, that is shipped with the moment of sampling can be separated.

### 2.3 Stage of the analysis of the sample by spectrophotometry

Samples already taken diluted as much as 10 times used a 100 mL measuring cup. The samples already diluted taken as many as 10 mL and then put in a container of the sample is then mixed with a solution of $NH_4OH$ 0.25 mL of 0.5 N as much as using a micropipette and guarded condition at a pH of 7.9 $\pm$ 0,1 with phosphate buffer solution plus way using the dropper drops. The samples are then coupled solution of 0.1 mL is as much as amino antipyrine while stirring and plus 0.1 mL of an aqueous solution of potassium ferricyanide and stand for 15 min. After 15 min of a sample cuvet put in on spectrophotometry then read absorbance at a wavelength of 500 nm.

### 2.4 Adsorption rate and kinetic models

The rate at which pollutants are removed from aqueous solutions is another crucial factor in the selection of suitable adsorbent for use in wastewater treatment facilities [19]. Depending on the concentration of methylene blue, the time required for methylene blue to achieve adsorption equilibrium has been reported by many studies to range from few min to few hours [20,21,22]. Methylene blue is the same as phenol, which is an aromatic hydrocarbon compound. These oxygen functional groups are important for the adsorption of heavy metals. Some earlier researches showed that the adsorption mechanism of biochar on heavy metals involved electrostatic attraction, ion exchange, physical adsorption, complexation, precipitation and a combination of multiple forces [23]. The rate of adsorption equation can be given as the reaction kinetics equation as follows [24] :

$$R_{ads} = k\ C^x \qquad \ldots(1)$$

Or if expressed with the Arrhenius equation, we get:

$$R_{ads} = A\ C^x \exp\left(-E_a/RT\right) \qquad \ldots(2)$$

### 2.5 Mathematical formulation process of adsorption

The mathematical formula commonly used to explain the mechanism of adsorption, especially in the process of colloid removal, is given as follows [24]:

$$\ln C/co = -kt^{1/2} \qquad \ldots(3)$$

The formula describes the relationship between changes in absorbent concentration to the function of time. As explained earlier, the speed of adsorption is strongly influenced by factors, such as the size of the adsorbent granules, the ratio of the mass of the adsorbent per mass of solution and temperature. These factors have a major role in determining the price of the adsorption speed constant (k). These factors will be reviewed in this study. Generally, the relationship between changes in absorbent concentration to the three factors above is given in the following equation [24]:

$$\ln\frac{c}{co} = -\left[k_0\right]\exp\left(-\frac{\Delta E}{RT}\right) d^{n1}\ r^{n2} \left(t\right)^{1/2} \qquad \ldots(4)$$

in the formula above, constants need to be determined through research, that is $n_1$, $n_2$, ko and $\Delta E$. Research carried out by measuring the speed of adsorption (comparison between adsorbate concentration before and after operation adsorption takes place) as a function of time, with the variation temperature operating, grain size and the ratio of the mass of adsorbent per mass of solution.

## 3. RESULT AND DISCUSSION

In this study, the method has been made to lower the concentration of phenolic compounds in water by using activated carbon adsorbent. It is generally believed that total phosphorus adsorption occurs by physical adsorption and the adsorption of ammonia-nitrogen occurs by physical adsorption and microbial action [25,26]. On the research of the adsorption method is used by using types of local charcoal activated products. Of the research data generated, the relationship between the concentration ratio of rest against the initial concentration (C/C0), temperature (T), grain di-

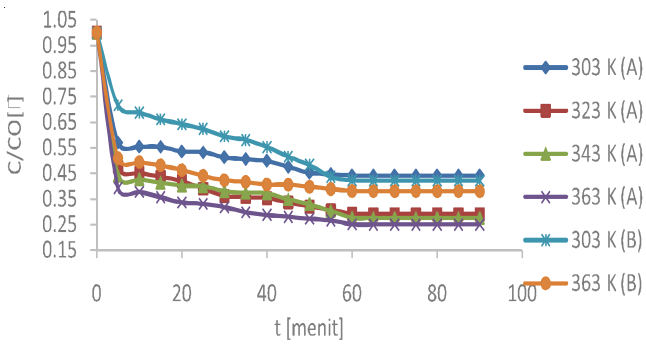


**Figure 1**. *The ratio of the concentration of phenol compounds in residual solution of initial concentrations of phenol compounds against C/CO as a function of time (t) on a wide range of operating temperatures (T)*

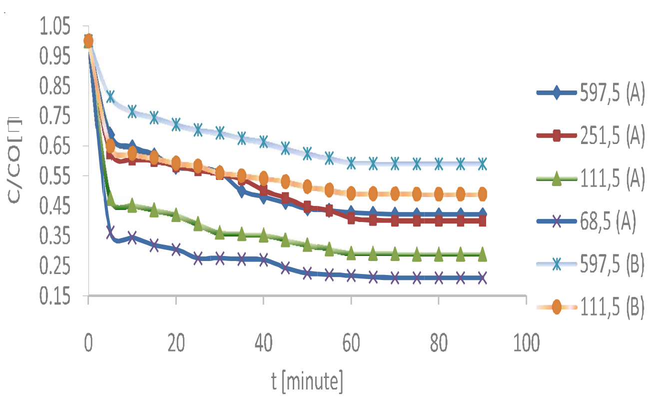


**Figure 2**. *The ratio of the concentration of phenol compounds in residual solution of initial concentrations of phenol compounds against C/CO as a function of time (t) activated carbon range of grain size (d)*

ameter (d) and the ratio of the mass of adsorbent per mass of solution (r), as a function of time (t). Then the calculated the adsorption kinetics formulations.

### 3.1 Temperature variations

This step is carried out using activated carbon with a grain diameter size -100 + 200 mesh (111.5 $\mu$m) and mass activated carbon 20 gm. Shaker water bath temperature varied 303K, 323K, 343K and 363K. Data retrieval is performed every 5 min, for 1 hr. Research data are obtained as shown in figure 1. Based on figure 1, tt can be seen that during the process of adsorption takes place residual phenol compounds concentration ratio in the solution of the initial concentration of phenol compounds against the smaller. This shows that the phenol compounds increase by the time. Study data also showed that the operating temperature rises (in the same operating time), the ratio of the concentration of phenol compounds in solution against the rest of the initial concentration of the lower, or in other words, the phenol compounds adsorption more and more. The chemical properties of phenol is a colourless solid that readily melts and dissolves well in water. So it takes energy from the outside to be able to release the bonds between the molecules are hydrophilic phenolic with water, so that it can bind with molecules on the surface of the solid adsorbent activated carbon which is hydrophobic. Besides, the high operating temperature caused the molecules adsorbate, and adsorbents have high mobility, so it's easier for the molecule phenol to adsorp into porous activated carbon. So it can be concluded that the rate of adsorption is increasingly rising with the increase of the operating temperature.

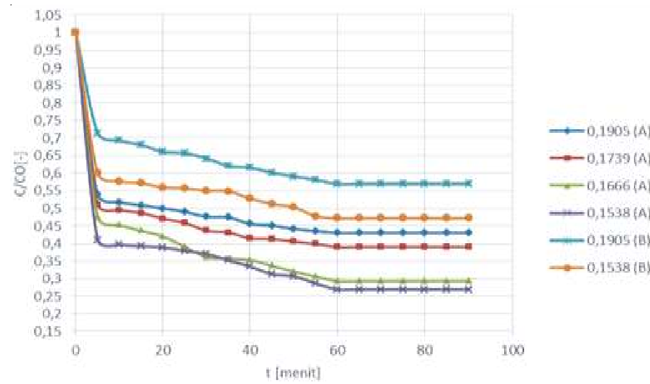


**Figure 3.** *The ratio of the concentration of phenol compounds in residual solution of initial concentrations of phenol compounds against C/CO as a function of time (t) on a variety of active carbon/mass ratio of the mass of the solution (r)*

### 3.2 Grain size variation of activated carbon

This step is carried out using a shaker water bath temperature of 323K, mass activated carbon as much as 20 gm and activated carbon which varied with the size of the diameter of A grain-20 + 45 mesh (597.5 $\mu$m), type B with a grain diameter size-45 + 100 mesh (251.5 $\mu$m), type C with the size of the diameter of a grain-100 + 200 mesh (111.5 $\mu$m) and type D with size diameter-200 + 230 mesh (68.5 $\mu$m). Data retrieval is performed every 5 min, for 1 hr. Research data are obtained as shown in figure 2. Research data shows the tendency that the smaller the size of the diameter of granular activated carbon used (within the same operation), the fewer remaining phenol compounds in solution or the more molecules of phenol can adsorb. This trend can be seen in figure 2. This is because the smaller the grain size of used adsorbents, extensive contacts (wide-field adsorption) between the

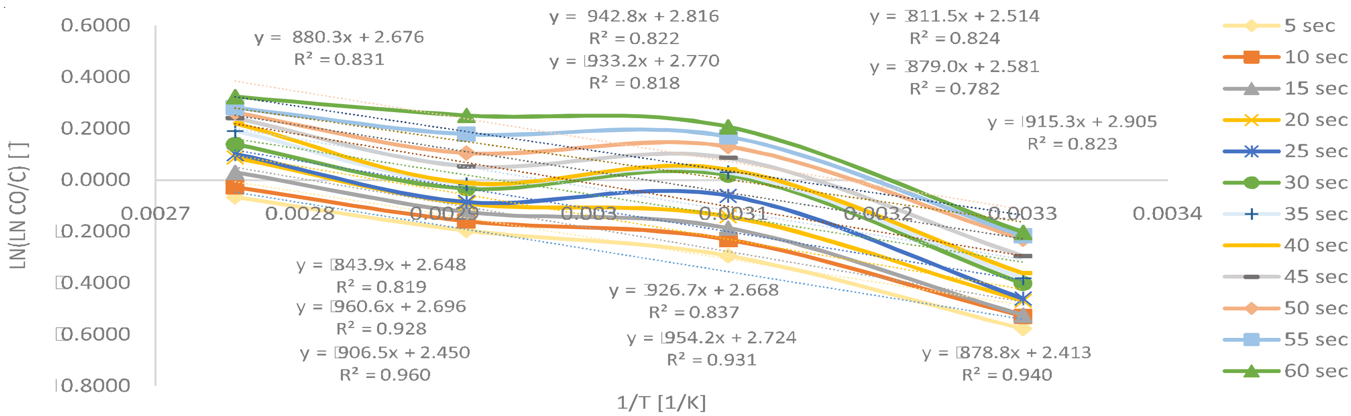


**Figure 4.** *Logarithmic ratio of initial phenol concentration to residual phenol as a function of time (t) at various operating temperatures (1 / T)*

adsorbents with a substance that will adsorb become increasingly large, different when compared with the larger grain size with the same amount of adsorbent, adsorption results will be less than with a smaller grain size.

### 3.3 Variations in the ratio of the mass

This step is carried out using a shaker water bath temperature 323K, activated carbon with the size of the diameter of a grain-100 + 200 mesh (111.5 $\mu$m) and the mass of the activated carbon varied by as much as 5 gm, 15 gm, 20 gm and 30 gm. Data retrieval is performed every 5 min, for 1 hr. Research data are obtained as shown in figure 3. Figure 3 indicates that the greater the ratio of the mass of activated carbon toward the mass of solution, the smaller the ratio between the concentration of phenol in residual solution against the initial concentration. This shows that a growing number of phenolic adsorb within the same operation or adsorption rate of increase over the rise in the ratio of the mass of active carbon toward the mass of solution. This is because the larger the ratio of the mass of a carbon active against the mass of the solution, then the more spacious also contact (wide-field adsorption) between the adsorbents with absorbate so that phenolic adsorb more and more.

### 3.4 The relevance

The relevance between the ratio of phenol concentrations to concentrations to initial phenol concentrations (Ln [In (C / C0)]) with time (t) at various operating temperatures (T). Based on figure 4, 12 slopes were obtained because there were 12 times variation. As for the local activated carbon, 12 slopes were also obtained in each time variation -1294, 9175, -1159, 2230,-1046,6438,-1015,9691,-1017,6813,-925.6745, -875 , 1545, -769,1255, -563,0307,-433,4763, -237,1064, -214,4296, which are then added up and averaged to produce a slope with a value of -ΔE = -95,7465 Joules/mol.

## 4. CONCLUSION

Local charcoal activated carbon effective and efficient in the waste adsorb by calculating the kinetics adsorption. The rate of adsorption of phenol by activated carbon adsorbent rises with rising operating temperature (T) and the ratio of the mass of active carbon toward a solution (r). And declining with a diameter of activated carbon (d). The equation kinetics for adsorption of phenol using local charcoal activated products based on graphics method is as follows:

$$\ln\frac{c}{co} = -\left(0543\ \exp\left(\frac{-218{,}6897}{RT}\right) k^{0.2828}\ r^{-1{,}5018}\ t^{2}\right)$$

with the average relative error of 5.16%. The second equation above applies to the range of values of T from K to 303 K, d from 363-20 + 45 mesh (597.5 $\mu$m) to the 200 + 230 mesh (68.5 $\mu$m) and r from 0.1905 to 0.1538.

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