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Determination of Maximum Adsorption Capacity of the Napa Soil on Chromium Ions (III)

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Abstract — Determination of maximum adsorption capacity of the Napa Soil on chromium ions (III) has been investigated, the aims of the research for to know the characteristics and maximum adsorption capacity of Napa soil on chromium (III). Experimentally, all steps were performed in series of experiment using a continuous techniques with respect to the influence of pH, initial chromium concentration, particle size, temperature heating adsorbent, solution flow rate, and determined the maximum adsorption capacity and adsorption affinity adsorbent was determined by the *Langmuir Isotherm Equation* and metal analysis carried out by Atomic Adsorption Spectrophotometer instrument. The results of this study showed that optimum condition at pH 5, initial chromium concentration is 250 mg/L, particle size is 850 μm, temperature heating adsorbent on 125°C, solution flow rate is 20 drops/min. Showed has the maximum adsorption capacity of the Napa Soil on chromium ions (III) is 3,28 mg/g.

Keywords—Napa Soil, adsorption, chromium (III), adsorption capacity

I. INTRODUCTION

Along with increasing advances in technology and the development of industrial activities, in addition to the positive impacts also have negative impacts. Rapidly growing industry also means increased waste produced and will pose complex problems. Hazardous waste and has a high toxicity generally derived from industrial waste, especially the chemical industry. Pollutants that are of concern are heavy metal ions. This is due to the ions are toxic even at low concentrations (ppm) and generally as a major pollutant to the environment. One type of heavy metal chromium is a metal that is widely used in various manufacturing industries, ranging from as simple as household appliances to large industries with high technology such as satellite

Heavy metal ions such as ions of chromium (III) or Cr^{+3} can cause lung cancer, damage to liver and kidneys and can cause irritation to the skin [1] and has accumulated sensitivities, when these ions exist in the body of living beings will be congested and at certain concentrations can cause poisoning [2]. The presence of Cr in the environment would need to get more attention, because the levels of chromium exposure limit for Cr only 0.05 ppm [3]. By him it was expected that Cr in waters there, given the very small concentration limits allowed and the danger they pose (toxicity), it is necessary handling of the heavy metal waste before it is supplied to the eventual disposal into the environment.

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Efforts in dealing with wastes containing heavy metal ions has been done and needs to be developed. Approach that has been done to overcome this is through immobilization with deposition techniques, ion exchange and the use of adsorbents (absorbent) [4]. Methods have been developed in general effectiveness is low. Research to find a method of waste handling heavy metal ions especially Cr^{+3} ions which have a higher efficacy need to be developed [5]. From the analysis of the chemical composition of the napa soil using XRF known napa soil is soil that has a high alumina fused silica. The chemical composition of Napa soil is 70.84% SiO_2, 20.72% Al_2O_3, 3.57% Fe_2O_3, CaO 2.32% [6]. Based on the composition of the Napa soil contained silica alumina, and is expected to napa soil is an inorganic material that is very valuable and can potentially be used to study the development of inorganic materials such as adsorbents, catalysts, and additives in the cement industry.

Adsorption is the process of absorption of a substance on the surface of adsorbent and adsorption isotherm patterns meet. Bonds between the substances are absorbed by the absorbent (adsorbent) can occur in physics and chemistry, forming a single layer on the surface of the absorbent (monolayer adsorption) [7]. Adsorption capacity is affected by the presence of siloxane groups (Si-O-Si) and silanol groups (Si-OH) in an adsorbent [8]. Therefore, the aims of this study to determine the metal ion adsorption capacity of Cr^{+3} using Napa Land adsorbent can later be developed further in the provision of adsorbent to cope with heavy metal ions Cr^{+3} particularly well in the laboratory and on an industrial scale.

II. EXPERIMENTAL

A. *Tools and materials*

The equipment used is a glass like glass cup, stirring rod, flask, beakers, pipette, pipette peck, analytical balances, hot plates, columns, standards and clamp, funnel, evaporating dish, filter paper, stative funnel, sieve, pH meter, magnetic stirrer, oven, desiccator, thermometer, Atomic Absorption Spectrophotometer.

The materials needed include Napa Land, distilled water, standard chrome Ocean, HNO3, NH3, glass wool.

III. PREPARATION OF ADSORBENT

Napa Soil samples in form of granules washed with distilled water, oven-dried, finely milled and sieved with a certain particle size sieve, then packed into a column that basically placed in glass wool. Prior to use the column saturated with distilled water and ready to be contacted with a solution of Cr (III) with a continuous system.

IV. ANALYSIS OF THE METAL CONTENT

In the continuous systems, determination of the concentration of metal is done by flame AAS (analys 100), with air-acetylene fuel at the appropriate wavelength. Number of ions that are absorbed by the adsorbent is the difference between the ion concentration at equilibrium (in filtrate / eluent) with initial ion concentration. The amount of adsorbed metal is expressed as weight (mg) adsorbed metal per weight (g) of adsorbent used.

V. CONTINUOUS SYSTEM EXPERIMENTS

1) *Effect of heating adsorbent on chromium adsorption*: Prepared six columns, each packed with adsorbent napa ground heated to a certain size (in the oven) with varying heating temperature (heated for 3 hours), respectively at normal temperature (270C), 50, 75, 100, 125, and 1500C. Each column was contacted with 25 ml of Cr (III). Treatment and determination of the amount of metal absorbed performed as in steps B and C.
2) *Effect of flow rate on chromium adsorption*: A total of 25 ml solution of Cr (III) at pH and concentrations of certain work flowed through the column with a flow rate of 20, 30, 40, 50, 60 drops / min. Treatment and determination of the amount of metal absorbed performed as in step B and C..
3) *Effect of particle size on chromium adsorption*: The column packed with adsorbent napa soil with particle sizes 833, 850, and 1,700 lm and heated to the optimum temperature was then contacted with 25 ml of a solution of Cr (III) with the optimum flow rate. Treatment and determination of the amount of metal absorbed performed as in steps B and C.
4) *Effect of pH on chromium adsorption:* 25 ml solution prepared Cr (III) at pH 1, 2, 3, 4, 5 and 6 then eluted solution into the column with the heating temperature, adsorbent particle size and optimum flow rate. Treatment and determination of the amount of metal absorbed performed as in steps B and C.
5) *Effect of initial chromium concentration on adsorption process*: 25 ml solution prepared Cr (III) with concentrations of 50, 100, 150, 200 and 250 mg / l at pH optimum, then the solution into the column eluted with the heating temperature, adsorbent particle size and optimum flow rate. Treatment and determination of the amount of metal absorbed performed as in steps B and C

VI. DATA ANALYSIS TECHNIQUES

Concentration of each metal at equilibrium and the concentration initially determined Atomic Absorption Spectrophotometry. Amount of metal absorbed by the adsorbent is the difference between metal concentrations at equilibrium with metal komsentrasi early. The maximum amount of adsorbent uptake was determined by the equation of Langmuir adsorption isotherm, which can be written in the form of a linear equation [9]:

$$\frac{C}{x/m} = \frac{1}{(x/m)_{mak}k} + \frac{1}{(x/m)_{max}}C \quad (1)$$

Where, x / m is the adsorbed metal milligrams per gram of dry soil napa; k is the equilibrium constant (affinity constant uptake), c is the concentration of free ions when balanced (mg/L); $(x/m)_{max}k$ is milligrams of metal absorbed on saturation (maximum absorbance capacity), can also be written with the notation b. If the plot of C/(x/m) versus c produces a straight line, then the uptake affinity constants (k) and the maximum uptake capacity $(x/m)_{max}$ can be determined from the slope and intercept [10].

VII. RESULTS AND DISCUSSION

A. *Effect of heating adsorbent on chromium adsorption*

Heating the sorbent can increase the absorption capacity of the adsorbate. Heating is done to enlarge the pores so that the adsorbent will increase the efficiency of absorption. Besides heating the adsorbent done to enable the physical surface without changing its chemical properties, so the adsorbent pores are more open and are expected to increase absorbency. Figure 1 shows the absorption capacity as a function of heating temperature adsorbent napa soil.

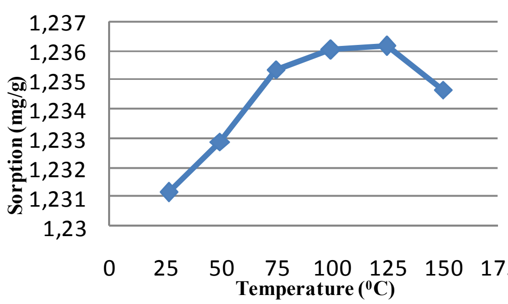

Figure 1. Effect of heating Adsorbent for Adsorption of Cr (III) (2 g napa land, 25 mL of Cr (III) 100 mg / L, pH 4)

Results of this study indicate a warming influence on the adsorption Cr (III) of adsorbent napa soil. Sorption capacity of Cr (III) on the adsorbent increased the temperature up to 1250C with absorption efficiency reaches 99.62%. This is due to have cut off the water to the hydrogen bonding between silanol groups (Si-OH) or between water with siloxane groups (Si-O-Si), so that the water content to be less, the loss of water molecules from the surface of silica causes the silica surface area and volume pore becomes larger so that the process of physical adsorption and chemical adsorption become more effective and efficient. Napa soil absorption decreased sharply, it is heating adsorbent at 150^0C possible there has been a breakdown of organic compounds that are likely involved in the absorption process by forming organometallic bond and electrostatic interactions. [11] Wendlandt stated that the effect of soil warming in general showed thought to be loss mass starts at temperatures of 150-180^0C, effect of impurities hidroskopik hidroskopik or mixed with organic materials that are volatile. Organic materials contained in the soil in general began to decompose at temperature of 210-240 °C and completely decomposed at temperature of 500°C.

VIII. Effect of Flow Rate on Chromium Adsorption

Flow rate of the continuous system is closely connected with the contact time between the adsorbate with adsorbent, the greater the flow rate will reduce the contact time between the ion Cr (III) with an active group napa ground, so that the adsorption capacity of Cr (III) decreases.

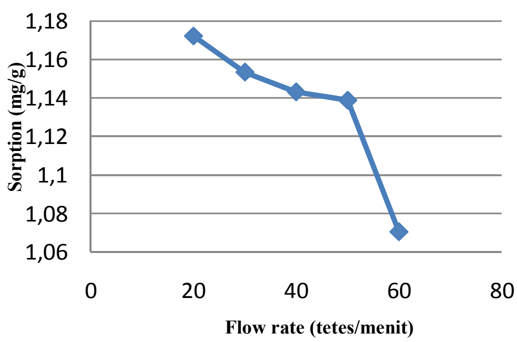

Figure 2. Effect Eluent Flow Rate on Adsorption of Cr (III) (2 g napa Land, 25 mL of Cr (IIII) 100 mg / L, pH 4)

Curve in Figure 2 shows the absorption capacity as a function of eluent flow rate. The results showed that the slower flow rate, the more Cr (III) is absorbed because the contact time between the adsorbent napa soil with a solution so that the longer the adsorption process takes place more perfect. In the eluent flow rate is rapid, Cr (III) is absorbed much less because only little interaction between Cr (III) with napa soil adsorbent so that the adsorption process is not perfect.

During the contact between the adsorbate with the adsorbent, the adsorption process will continue until a balance is achieved between both the adsorbent and adsorbate. If the flow rate used is too small, then the resulting contact time will be even greater, resulting in the adsorption capacity of chromium (III) will be even greater. By the time the state of the adsorbent and adsorbate start equilibrium, then the amount of contact time is not going to affect the adsorption capacity is generated. If the flow rate used is too large, it can reduce the contact time between the adsorbent with adsorbate.

IX. Effect of Particle Size on Chromium Adsorption

Wennerstrum [12] states resize aims to 1) generate the appropriate size with the process or the use of such materials, 2) produce a substance that can move smoothly during the process, 3) improve the mixing of different ingredients and avoid separation of materials different intermingled, 4) increase the surface area to increase the reactivity or drying efficiency, and 5) keep the bulk density of the material by exploiting differences in the size of the material that fills the gaps with adequate space by particles with a smaller size.

Results of research that has been done is shown in Figure 7. The lower the particle size the higher absorption of chromium. Ion absorption of Cr (III) 99.31% at optimum conditions. Munaf and Zein [13] reported that, when the particle size of the adsorbent increased, the adsorption of metal ions decreases. Similar statements have been reported by [14]. Thereby this phenomenon may be due to the fact that small particles have surface area and the number of larger sites.

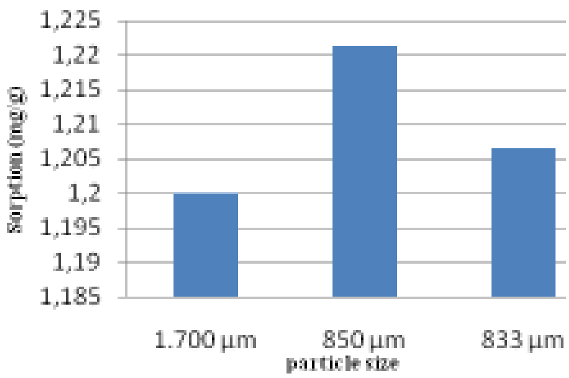

Figure 3. Effect of Adsorbent Particle Size on Adsorption of Cr (III) (2 g napa Land, 25 mL of Cr (III) 100 mg / L, pH 4)

In Figure 3 shows that the particle size greatly affect absorption napa soil to Cr (III). with a percentage of 99.31% absorption. Result of optimum particle size for maximum absorption is 850 µm. The data obtained showed that the absorption capacity of the napa soil with 850 µm particle size is lower than the particle size of 833 µm. It is alleged, among other things, due to the continuous system of napa soil with a smaller particle size (fine) will solidify like clay in the column, so it can pass through the column eluent is less than the size of the particles larger napa soil, so Cr (III) which is absorbed by the soil adsorbent napa also smal.

X. Effect of pH on Chromium Adsorption

According Riapanitra [15] pH affects the surface charge of the adsorbent, the degree of ionization and any species that can be absorbed in the adsorption. PH value can also affect chemical equilibrium, both the adsorbate and the adsorbent. In this pH variation possibility of chemical bonds between the adsorbent with adsorbate can occur [16]. On Figure 4 It is known that the optimum conditions for ion uptake of Cr (III) at pH 5 with efisiesnsi absorption 99.98%. At low pH the absorption of all the low metal ion. This is because at low pH the adsorbent surface is surrounded by H^+ ions (due to functional groups on the adsorbent contained protonated). In acidic conditions also positively charged adsorbent surface, which will cause repulsion occurs between the adsorbent surface with metal ions, so that the adsorption is low [17]. At near-neutral pH also decreased absorption efficiency. This is because the near-neutral pH metal ions can undergo hydrolysis reactions in solution so that it is unstable in the original form of the metal ions and cause the soil's ability to absorb declining napa. While at alkaline pH, metal ions can form a hydroxide precipitate so that the efficiency of absorption is difficult to determine

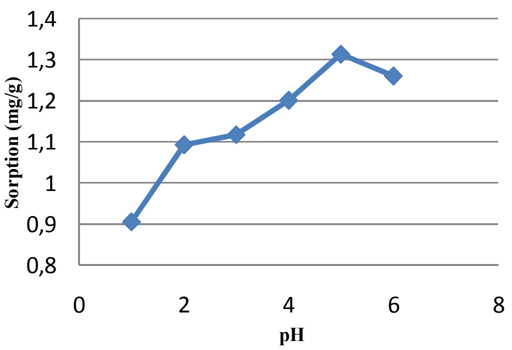

Figure 4. Effect of Initial Solution pH Cr (III) to the napa land (napa Land 2 g, 25 mL of Cr (III) 100 mg / L)

XI. Effect of Initial Chromium Concentration on Adsorption

The results of absorption capacity is shown in Figure 5. Based on Figure 5 it can be seen that, the efficiency of absorption of Cr (III) increased with increasing initial chromium concentration. In the case of low chromium concentrations, the ratio of initial number of moles of chromium ions available on the small surface area of the adsorbent and the subsequent adsorption of chromium metal in solution at high concentrations will rise up to the full site on the adsorbent [18].

After ion Cr (III) is absorbed reaches a maximum, then the subsequent increase in the relative concentrations no longer increase the absorption capacity of the Land napa, because the active site on the surface of the soil has been saturated by napa Cr (III) and has reached equilibrium in the system. From the data obtained shows that the ion Cr (III) adsorbed increased relatively sharply with increasing concentration of the solution is contacted with an adsorbent land napa. Value of maximum absorption occurs at a concentration of 250 mg / L with the absorption capacity of 2.46 mg / g.

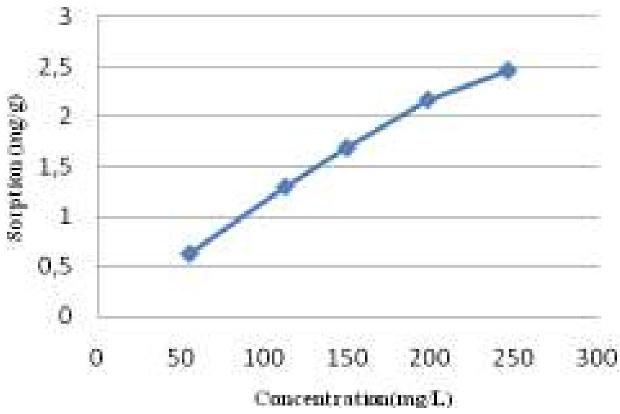

Figure 5. Effect of Concentration of Cr (III) Adsorption on napa land (2 g napa Land, 25 mL of Cr (III), pH 4)

XII. Determination of Maximum Absorption Capacity of the Napa Soil Chromium Ion (III)

Adsorption isotherm study conducted using Langmuir isotherm adsorption equation. This is because in this study it is assumed that adsorption occurs only on a single layer of molecules adsorbed on the surface of the adsorbent alone. Besides the adsorption process is physical adsorption process because it occurs at room temperature and atmospheric pressure so that the Langmuir equation better accommodate the data in this study. By using the Langmuir adsorption isotherm equation can be determined maximum absorption capacity of the soil napa to Cr (III).

When the data were obtained above satisfies the equation, then plot C/m to C would result in a straight line as shown in figure 6 is concluded that the adsorption of Cr (III) by the napa soil meet the Langmuir adsorption isotherm equation with a correlation coefficient (R^2) close to 1, so that sorption affinity constants (K) and maximum uptake capacity ($(x/m)_{mak}$) can be determined with slope $1/(x/m)_{mak}$ and intercept $1/(x/m)_{mak}K$. Value of K, and $(x/m)_{mak}$ obtained for ion Cr (III), respectively, 0.07 and 3.28 mg / g..

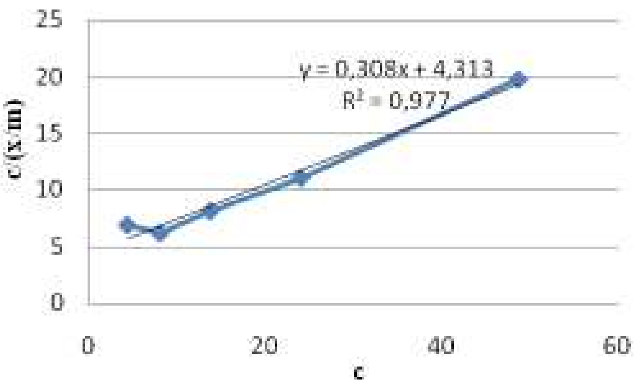

Figure 6. Linearity curve of the Langmuir adsorption of metal ions chromium (III) by pure napa soil

In the adsorption process of Cr (III) by napa Soil adsorption occurs in physics and chemistry. Predicted interaction between the ions Cr (III) with the adsorbent is due to the van der waals with weak bonds. At acidic pH, the adsorbent will be positively charged due to siloxane groups (Si-O-Si) and silanol groups (Si-OH) protonated through the free electron pair so as to permit electrostatic interactions.

In general, more napa Land adsorbent and negatively charged ions of Cr (III) is positively charged, so that the absorption of Cr (III) high. This is in accordance with Nurhasni [19] which states that an absorption ability can be affected by the nature of the adsorbent and adsorbate charge. This is related to the attraction and repulsion force between the active site of the adsorbent with metal ions to be absorbed.

XIII. CONCLUSIONS

Based on the results of research conducted can be concluded as follows:

1. From the calculation of the Langmuir isotherm equation obtained maximum absorption capacity of the soil Napa adsorbent for Cr (III) ion is 3.28 mg per gram of adsorbent.
2. Napa Land optimum conditions as adsorbent is at pH 5, the optimum concentration of 250 mg / L, particle size 850 μm and temperature of heating 125°C, and the optimum flow rate of 20 drops / min and the adsorbent at with absorption efficiency of 99.89% .

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