CHAPTER 1

INTRODUCTION

1.1 Background

Wastewater discharged by industrial activities is often contaminated by a variety of toxic or other harmful substances which have negative effects on the water environment. For example the industry of metal finishing and electroplating units are one of the major sources of metal ions or heavy metals such as copper, zinc, chromium which contribute greatly to the pollution load of the receiving water bodies and therefore increase the environmental risks. The undesirable effect of this hazardous chemicals can be avoided by the treatment of their waste water prior to discharges.

Industrial wastewater treatment is the process of cleaning wastewater which was contaminated by industrial activities. The process is very important and essential to ensure the contaminated wastewater do not exceed the permissible limit set by the government prior to discharge to the environment. Beside that the treated wastewater can be recycled and reused to reduce the use of fresh water and this is good for cost reduction and optimization.

The development of effective treatment options for metal ions contaminated wastewater is a significant technical and practical challenge. In addition, effective treatment is often challenging due to high toxicity, volatility and environmental mobility of metal ions and the varied nature and composition of industrial wastewater products.

Consequently, there is a growing need for the alternative methods for the elimination of metal ions. Activated carbon was especially known for the effectiveness in removing organics chemical from wastewater, it is also known for the effectiveness in removing metal ions pollutants. In general, carbon adsorption is not nearly effective at removing metal ions and inorganics pollutants as it is in removing organic compounds.

Therefore, the adsorption capacities and the feasible removal rates must be substantially boosted with modification of the activated carbon with suitable chemicals. For this reason, modification and impregnation techniques were used to increase surface adsorption and so removal capacity and to add selectivity to the activated carbon. For removal of copper ions, one of the appropriate method is by using activated carbon with sodium acetate. By using this method, the adsorption capacity of the activated carbon will be increased.

1.2 Problem Statement

Carbon adsorption is a part of process involved in advanced or tertiary treatment of industrial wastewater. This step is very necessary to remove the organic contaminant which may cause resin fouling when it enters the ion exchange unit. After undergo adsorption process for period of time, the activated carbon need to be replaced, since it is concentrated with impurities. Instead of disposing the used activated carbon, it also can be regenerated and reused for cost optimization. Therefore, less frequency of regeneration is mostly desired and it can be achieved by modifying the surface of activated carbon to increase the adsorption capacity.

Copper is commonly traced in the industrial effluent and it need to be removed from wastewater due to its harmful and dangerous to human health.

1.3 Objectives

The objective of this project can be categorized into 4 objectives as follow;

1. To remove the Cu(ii) ions from industrial wastewater using activated carbon.
2. To know the removal mechanism of metal ions by activated carbon.
3. To know the regeneration of activated carbon.
4. To characterized the activated carbon before and after modification.

1.4 Scope of study

This study is about enhancing the effectiveness of industrial wastewater treatment focusing on the adsorption process. Therefore, it is necessary to understand the stages in treating the wastewater and which part the process involve adsorption. Industrial wastewater treatment is consist of a few stages which are pretreatment, primary treatment, secondary treatment and advance or tertiary treatment.

The pretreatment process is mainly to remove the large materials from wastewater that may hinder the following treatment.

In primary treatment, floating and suspended solids are settled and removed from sewage.Flow from the sewers enters a screen/bar rack to remove large, floating material such as rags and sticks. It then flows through a grit chamber where heavier inorganics such as sand and small stones are removed. Grit removal is usually followed by a sedimentation tank/ clarifiers where inorganic and organic suspended solids are settled out.
To kill pathogenic bacteria, the final effluent from the treatment process is disinfected prior to discharge to a receiving water. Chlorine, in the form of a sodium hypochlorite solution, is normally used for disinfection. Since more chlorine is needed to provide adequate bacteria kills than would be safe for aquatic life in the stream, excess chlorine is removed by dechlorination. Alternate disinfection methods, such as ozone or ultraviolet light, are utilized by some treatment plants.
Sludge that settles to the bottom of the clarifier is pumped out and dewatered for use as fertilizer, disposed of in a landfill, or incinerated. Sludge that is free of heavy metals and other toxic contaminants is called Biosolids and can be safely and beneficially recycled as fertilizer, for example.

Secondary Treatment. Primary treatment provided a good start, but, with the exception of some ocean outfalls , it is inadequate to protect water quality as required by the Department of Environment (DOE).

With secondary treatment, the bacteria in sewage is used to further purify the sewage. Secondary treatment, a biological process, removes 85 percent or more of the organic matter in sewage compared with primary treatment, which removes about 50 percent.

The basic processes are variations of what is called the "activated sludge" process or "trickling filters," which provide a mechanism for bacteria, with air added for oxygen, to come in contact with the wastewater to purify it.

In the activated sludge process, flow from the sewer or primary clarifiers goes into an aeration tank, where compressed air is mixed with sludge that is recycled from secondary clarifiers which follow the aeration tanks. The recycled, or activated, sludge provides bacteria to consume the "food" provided by the new wastewater in the aeration tank, thus purifying it.

In a trickling filter the flow trickles over a bed of stones or synthetic media on which the purifying organisms grow and contact the wastewater, removing contaminants in the process. The flow, along with excess organisms that build up on the stones or media during the purification, then goes to a secondary clarifier. Air flows up through the media in the filters, to provide necessary oxygen for the bacteria organisms. Clarified effluent flows to the receiving water, typically a river or bog, after disinfection. Excess sludge is produced by the process and after collection from the bottom of the secondary clarifiers it is dewatered, sometimes after mixing with primary sludge, for use as fertilizer, disposed of in a landfill, or incinerated.

Advanced or Tertiary Treatment. As science advanced the knowledge of aquatic life mechanisms and human health effects, and the need for purer water was identified, technology developed to provide better treatment. Heavy metals, toxic chemicals and other pollutants can be removed from domestic and industrial wastewater to an increasing degree. Methods of advanced treatment include microfiltration, carbon adsorption, evaporation /distillation, and chemical precipitation.

This study is focusing on the properties of the activated carbon and its application in wastewater treatment. Methods to modify its surface were identified and the selection was made by the targeted impurities. For this experiment, copper ion was used as the pollutant. Detail description of activated carbon is discussed in the next chapter.

After performing modification on to the surface of activated carbon, the adsorption study was conducted to see the effectiveness in adsorbing the copper ion. Therefore, deep understanding in the adsorption process must be gained. The mechanism of the adsorption process will be explained in the next section.

CHAPTER 2

LITERATURE REVIEW

2.1 Activated carbon

Activated carbon, also called activated charcoal, activated coal or carboactivatus, is a form of carbon that has been processed to make it extremely porous and thus to have a very large surface area available for adsorption or chemical reactions.

Due to its high degree of microporosity, just 1 gram of activated carbon has a surface area in excess of 500 m2, as determined typically by nitrogen gas adsorption. Sufficient activation for useful applications may come solely from the high surface area, though further chemical treatment often enhances the adsorbing properties of the material. Activated carbon is usually derived from charcoal.

There are 3 main forms of activated carbon which is granular activated carbon, powdered activated carbon and pelleted activated carbon. For this research is only focusing on granular activated carbon.

Actually the activated carbon is produced from variety of material such as coal, bituminous coal, bone, wood, coconut shell and so on. These base material undergo carbonization process, where they are heated at high temperature, normally in the range of 400-600° C to derive any volatiles. To activate the carbon, it is subjected to a second heat and steam treatment. Activation occurs by heating the material to an elevated temperature such as 800 – 900° C with steam or carbon dioxide to produce the carbon material that having high porosity and a specific surface area that maybe in access of 1000m^2/g.

Granular Activated Carbons are a very versatile group of adsorbents, with capability for selectively adsorbing thousands of organic, and certain in- organic, materials. From medicinal uses of powdered carbons in ancient Egypt, through charred interiors of whiskey barrels, carbon has been activated and used as an adsorbent for centuries.

Granular activated carbon adsorption has been widely used and successful for the advance treatment of municipal and industrial wastewater treatment. Granular activated carbon is used to adsorbed the relatively small quantities of soluble organic and inorganic compounds such as nitrogen, sulfides and heavy metals such as copper, chromium, zinc in the remaining wastewater.

2.2 Surface Modification

Based on the type and nature of thetargeted impurities, the surface of ACmay be modified to enhance the affinitytoward the desired impurity. As an inertporous carrier material having large specific surface area, AC is capable of attracting a variety of chemicals onto itshydrophobic internal surface. Dependingon the application, there are differentmethods to modify AC, which make thesurface accessible to a variety of reactants. In general, the surface modificationof AC is carried out after the activationstep. As shown in Figure 1, the modification can be categorized in three classes:chemical modification, physical modification and biological modification. Thechemical modification may further bedivided into two broad groups, those resulting in acidic and basic surface. Thethird type of chemical modification is thesurface impregnation of AC with activemetals and their oxides. The physical modification includes mainly heat treatment. The biological modification is arelatively newer approach, wherein biological methods of environmental controlcan be used for water treatment and otherapplications.

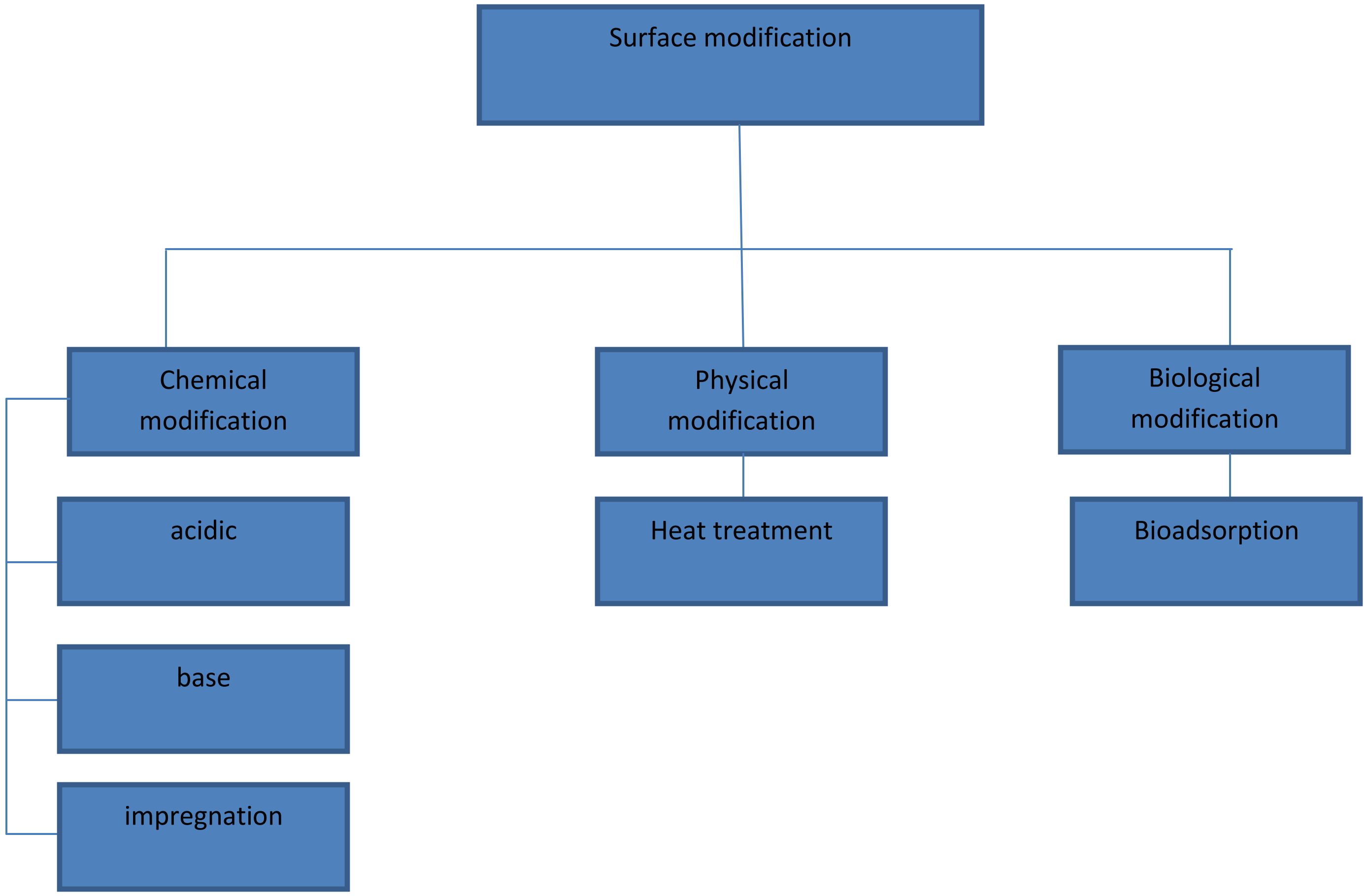

Figure 1 : surface modification method for activated carbon.

2.3 Chemical modification

It is well known that depending onthe presence of the surface functionalgroups, the activated carbon surface can show acidic,basic or neutral behavior. For the removalof heavy metals from water, acidic functional groups (i.e., oxygen functionalgroups containing proton donors) on carbon surfaces have been examined andfound to be highly favorable becausemetal ions have a tendency to form metalcomplexes with the negatively chargedacid groups. The major acidic groupspresent on activated carbon surface are shown in Figure 2.

All of the chemical treatments using oxidizing agents employed for creating acidic functional groups are associated with the reduction of specificsurface area and total pore volume,mainly due to the destruction of porous structures within activated carbon during oxidation.This is, therefore, a subject of researchinto alternative methods to increase theacidic surface groups without considerablepore destruction .

The chemicalmodifications of basic groups on the surface are carried out by treating activated carbon withchemicals such as aqueous ammonia andsodium hydroxide. Under alkaline (basic) solutions, it is expected that OH–ionsreact with the surface functional groupsof activated carbon.

The alkaline treatment of activated carbon isbeneficial in enhancing the adsorption ofespecially organic species (like phenol)from water.Surface impregnation is one of themost important chemical modifications.The term impregnation is defined as thefine distribution of chemicals and metalparticles in the pores of activated carbon. The following three reasons are suggested for theimpregnation of activated carbon.

1. To optimize the catalytic propertiesof activated carbon by promoting its built-incatalytic oxidation capability.
2. To promote synergism between activated carbon and the impregnating agent.
3. To boost the capacity of activated carbon as aninert porous carrier.

Recently, the impregnation of activated carbon with metals such as silver, copper, nickel,aluminum and iron has attracted greatresearch interest because of their significantly high sorption capacity for molecules the host activated carboncannot attract withoutthe impregnant.

Activated carbon impregnated withsuch transition metals has shown enhanced adsorption capacity and/or reactivity towardsfluoride, cyanide andheavy metals like arsenic in water.

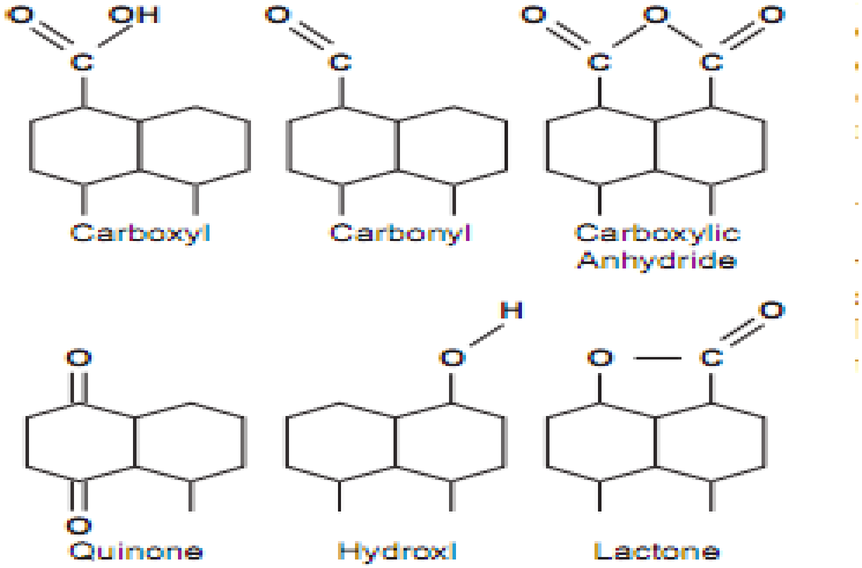

Figure 2: Acidic surface groups bonded to aromatic rings on activated carbon

2.4 Physical Modification

Heat treatment is the major methodso far reported for physical modification.AC treated thermally in an inert atmosphere generally becomes basic in nature.In general, all of the chemical modification techniques described above result inreduction of internal surface area andpore volume. Physical modification generally results in enhancement of physical characteristics (BET area and totalpore volume).

However, a significantdrawback of heat treatment isthat the surface oxygen functional groups (which are thermally unstable) can be decomposed athigh temperatures.This may sometimes result inlesser adsorption capacity. It isin this context that promisingmodification techniques suchas plasma treatment are beingdeveloped further to enhancethe chemical characteristicsand at the same time, thephysical characteristics to be preservedand/or improved.

2.5 Adsorption

The process of adsorption involve the separation of substances, termed and adsorbate from the liquid phase and the concentration at the surface of the material termed an adsorbent. The adsorption process take place in four more or less definable steps which are bulk solution transport, film diffusion transport, pore transport and adsorption..

2.6 Adsorption isotherm

Adsorption capacity of activated carbon increase as the concentration increase until the point of maximum saturation capacity in the standard condition. So, the activated carbon needs to be replaced or reactivated. Isotherms are empirical relations, which are used to predict how much solute can be adsorbed by activated carbon. Adsorption isotherm is developed by exposing a given amount of adsorbate in a fixed volume of liquid to varying the amount of activated carbon.

There a few types of isotherm exist, but the commonly used to describe adsorption characteristic of the activated carbon used in wastewater treatment is Freundlich Isotherm;

$$x/m = Kc^{1/n}$$

x = mass of adsorbate

m = mass of adsorbent

c = Equilibrium concentration of adsorbate in solution.

K and n are constants for a given adsorbate and adsorbent at a particular temperature.

1/n = Freundlich intensity parameter

The constants in the Freundlich isotherm can be determine by plotting log (x/m) versus log c and rewrite as

$$log(x/m) = logk + (1/n)logc$$

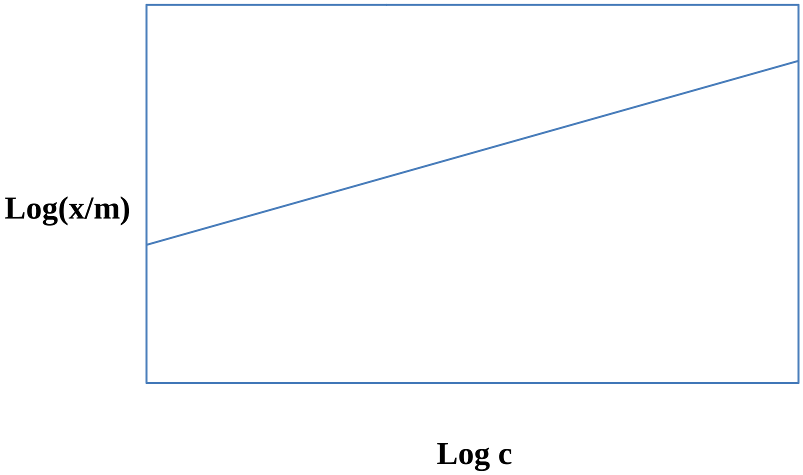

Figure 3: Freundlich isotherm

Another isotherm is called Langmuir Isotherm, which define as

x/m = abC/1+bC

x/m = mass of adsorbate adsorbed per unit mass of adsorbent, mg adsorbate/g activated carbon

a,b = empirical constant

C = equilibrium concentration of adsorbatein solution after adsorption, mg/L.

The constant of Langmuir Isotherm can be determined by plotting C/(x/m) versus C and making use of Equation rewritten as

$$C/(x/m) = 1/ab + 1/aC$$

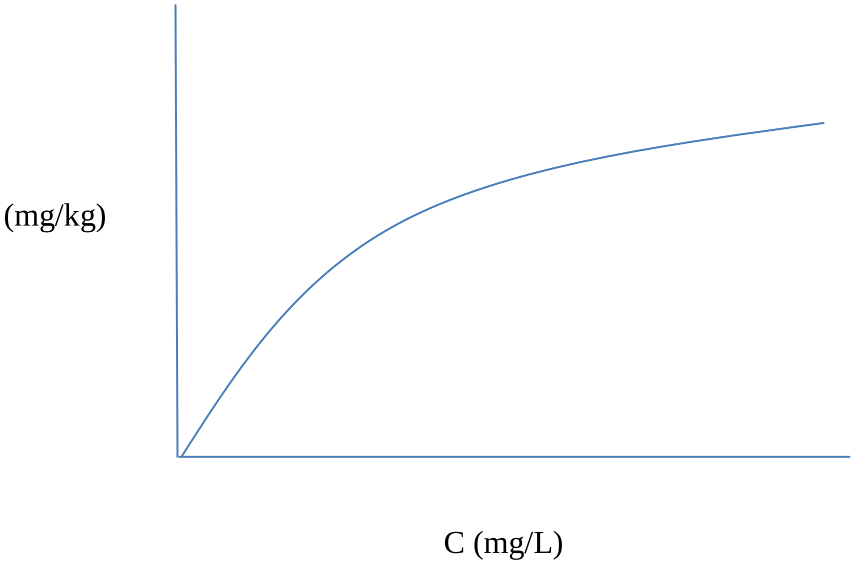

Figure 4: Langmuir Isotherm Curve

2.7Adsorption of metal ion

Metal ions is one of the hazardous chemical appear in the industrial wastewater. This contaminant mostly come from industry of metal finishing and electroplating units. Different heavy metals have different affinities for different functional group. In order to increase the adsorption capacity of activated carbon to adsorb metal ions, some modification must be done on it.

Nowadays we have a few methods can be used to modified activated carbon such as by using acids and react it with sodium acetate. In this experiment, I used sodium acetate to modify activated carbon and regeneration by using sodium hydroxide.

The modification on activated carbon will increase the effectiveness of adsorption of metal ions till few times compared to plain activated carbon. The adsorption capacity also depends to the percentage of modifier that we used to modified activated carbon.

2.8 Characterization

2.8.1 Atomic absorption spectroscopy

Atomic absorption spectroscopy (AAS) is a spectroanalytical procedure for the qualitative and quantitative determination of chemical elements employing the absorption of optical radiation (light) by free atoms in the gaseous state. In analytical chemistry the technique is used for determining the concentration of a particular element (the analyte) in a sample to be analyzed. AAS can be used to determine over 70 different elements in solution or directly in solid samples.

Atomic absorption spectroscopy (AAS) determines the presence of metals in liquid samples. Metals include Fe, Cu, Al, Pb, Ca, Zn, Cd and many more. It also measures the concentrations of metals in the samples. Typical concentrations range in the low mg/L range.

In their elemental form, metals will absorb ultraviolet light when they are excited by heat. Each metal has a characteristic wavelength that will be absorbed. The AAS instrument looks for a particular metal by focusing a beam of uv light at a specific wavelength through a flame and into a detector. The sample of interest is aspirated into the flame. If that metal is present in the sample, it will absorb some of the light, thus reducing its intensity. The instrument measures the change in intensity. A computer data system converts the change in intensity into an absorbance.

As concentration goes up, absorbance goes up. The researcher can construct a calibration curve by running standards of various concentrations on the AAS and observing the absorbances. In this lab, the computer data system will draw the curve for you! Then samples can be tested and measured against this curve.

2.8.2 Scanning electron microscope (SEM)

Conventional light microscopes use a series of glass lenses to bend light waves and create a mignified images. SEM creates the magnified images using electrons instead of light waves. The SEM shows 3-dimensional images at much higher magnifications. The image are very detailed. The images that created without light waves are rendered black and white. It can be used to estimate the pore size of activated carbon quantitatively. Pore entrances, clearly visible as dark irregular shapes on lighter membrane background.

CHAPTER3

METHODOLOGY

3.1 Research methodology

i Problem statement

- Identified issues that lead to the need of conducting research
- Significant of the project towards issue.

ii Literature review

- Review previous research done by others
- Make initial hypothesis based on their result and finding

iii Design the experiment

- Identified the equipments and chemicals needed.
- Develop procedures

iv Conduct experiment

- Modify activated carbon using sodium acetate
- Characterize the modified activated carbon
- Perform experiment where copper is the pollutant

v Result analysis

- Anylize the result
- Compare result with theory/hypothesis

vi Conclusion

- Conclude the finding
- Provide recommendation for improvement

3.2 Equipment and Chemicals

The experiment consist of two parts, firstly preparation of modified activated carbon using sodium acetate, nitric acid and citric acid. The remaining part is to conduct experiment of adsorption using activated carbon and modified activated carbon.

Equipment/ chemicals	**Description**
Fix bed column	Used for adsorption experiment
Oven	Used to dry activated carbon during modification process
AAS / spectrophotometer	To determine the concentration of copper
Nitric and citric acid	As modifier
Activated carbon	Adsorbent
Copper sulphate	As contaminant
Sodium acetate	As modifier

3.3Preparation of modified activated carbon

Plain activated carbon was sieved and washed with deionized water to remove any fine powder, then dried in the oven at the temperature 64°Cfor 24 hours.

One sample of plain activated carbon was reacted with 10% sodium acetate for 72 hours and another sample was react with 15% sodium acetate for 72 hours. Then, dried them in oven at temperature 60°C for 24 hours too.

This method is to produce modified activated carbon. Both of this modified activated carbon called MCA10 and MCA15, respectively.

3.4Method

Activated carbon was packed into a glass column (inner diameter 1cm and height 30 cm). feed solution was pump in a down-flow mode at flow-rate of 2ml/min. the samples were taken out to act asa reference, and of the effluent.The concentrations of metal ionwere determined with an atomicabsorption spectrophotometer The pH measuredwith an Orion model 525 A pH meter. Specific surface areas were measuredtoo.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Metal ions removal

This study was designed to increase the adsorptioncapacities and rates of Cu(II) removal by the modificationof the activated carbon. When the modifying chemicals areimmobilized at the surface of the activated carbon, theremoval mechanism is changed, because the functionalgroup at the activated carbon surface is replaced with a functional group from the modifier chemicals.

Removal capacity of plain and modified carbon

No	Adsorbent	Cu(ii) ion	
		mg	mg/g
1	Plain activated carbon /PCA	20	1.4
2	MCA10	33	2.2
3	MCA15	45	3.0

Table 1

The results in Table 1 show that the amounts of Cu(II)ions removed are in the order PCA < MCA10 < MCA15.The modifier chemicals increased the activated carboncapacity with increased concentration of the modifier.This result is similar to factthat the modification of activated carbon increased itscapacity. The adsorption capacity for MCA10 was2.2 mg/g and for MCA15 it was 3 mg/g.The ratio between the influent and the effluent concentration (Ceff/Cinf) versus time (in min) is plotted in Fig. 1.The higher the value of the ratio, the fewer metal ionsare removed.

Fig. 1 shows the values of the ratio versustime for PCA and for MCA10 and MCA15. Cu(II) ionremoval by the PCA was less than that by the MCAs,and the amount of Cu(II) ions removed from the solutionand the amount of Cu(II) ions removed from the solutionincreased with increased concentration of sodium acetate.The higher concentration of sodium acetate contained agreater number of carboxylic functional groups. As aresult, metal ion removal increased because of the additionof the carboxylic functional groups at the surface of theactivated carbon, and because the affinity of the carboxylicfunctional group for metal ions is very high.

Fig. 2 shows the pH of the effluent after passage overPCA, MCA10, and MCA15. The patterns are similar forall three, but the values are lowest for PCA. As can be seen,pH increased significantly at first contact and decreasedgradually thereafter. Increased effluent pH was reportedalso by Chen and Wang in their study, the pH increasedsharply to 7.3 at the beginning of the experiments,and decreased gradually to the pH value of the influent.

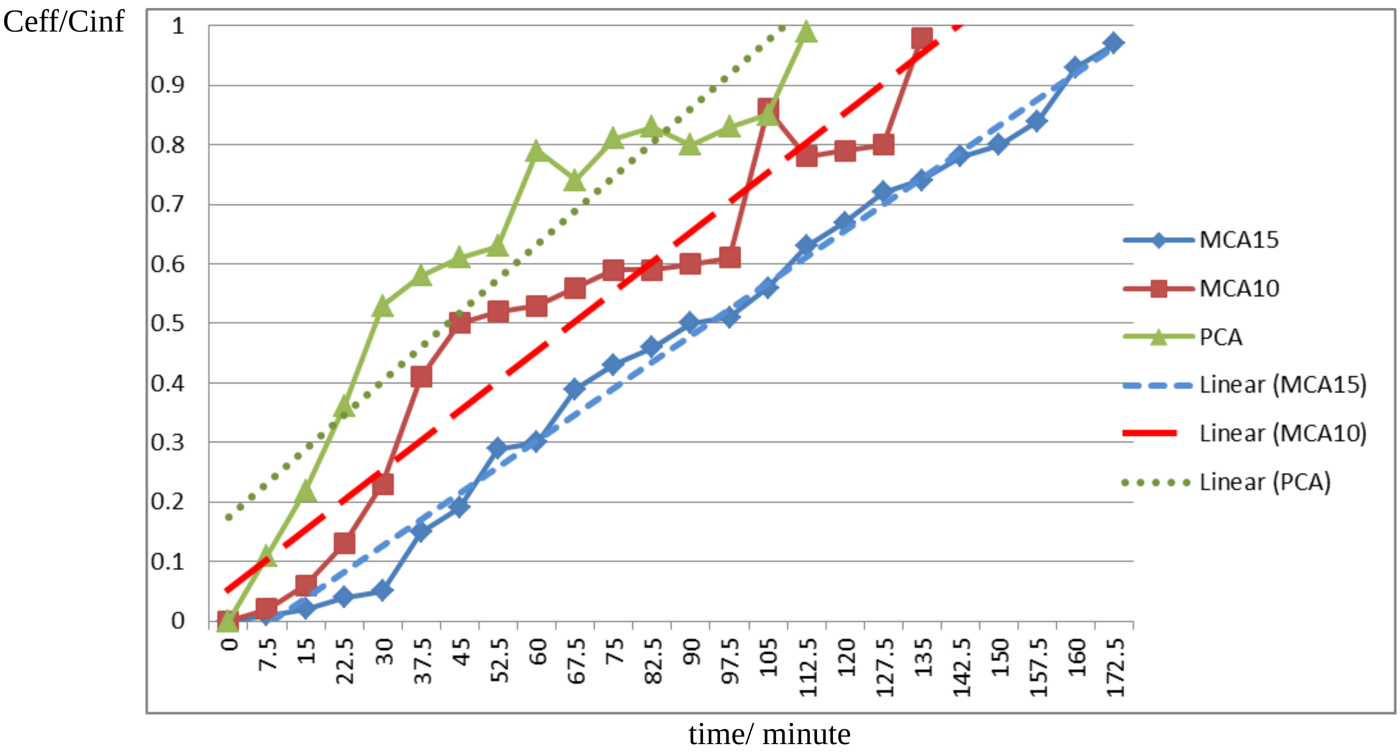

Figure 5: Cu(II) ion removal using the plain activated carbon, MCA10, andMCA15.

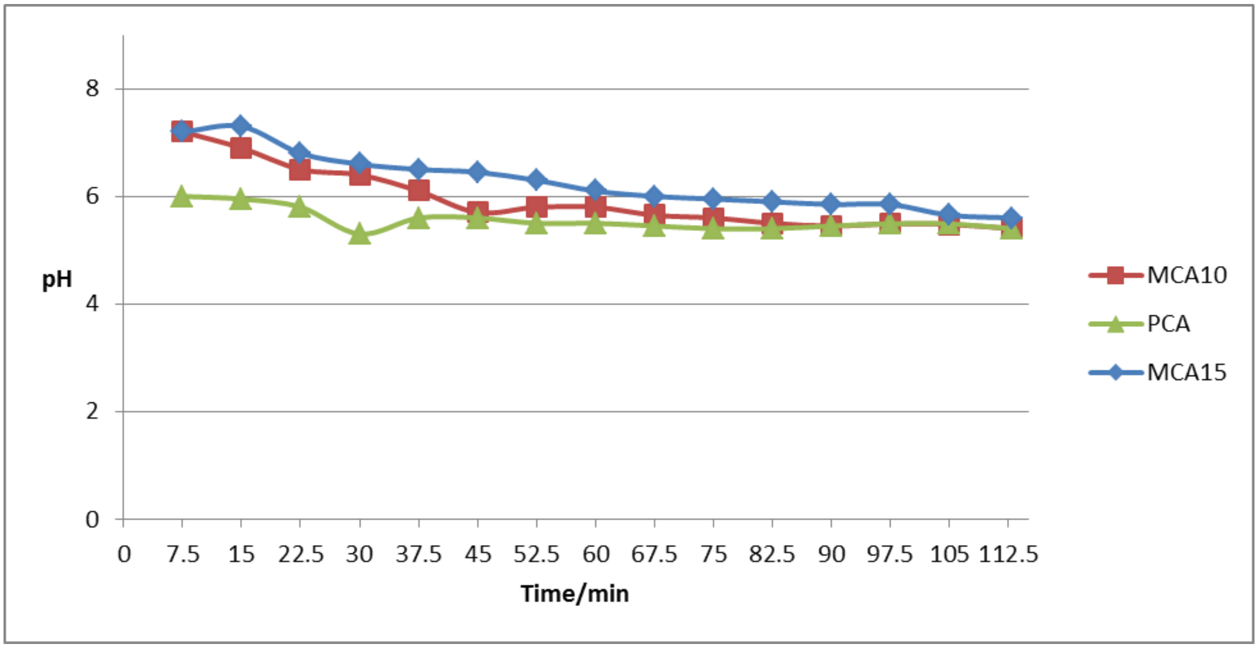

Figure 6: pH at the effluent of the plain activated carbon, MCA10, and MCA15

Adsorption of hydrogen ions from the solution and dissolutionof some impurities from the granulated activatedcarbon contribute to an increase in the pH of the effluent.The reaction of the functional group on the activated carbonsurface with metal ions also reduces the concentrationof hydrogen in the solution.this experiment yielded similar changes of pH. After increasing at the, the pH decreased graduallywhile the concentration of Cu(II) ions in the effluent solutionincreased. In this study, the change of pH was influencedby the reaction between the functional groups atthe surface of the activated carbon and metal ions, whichis related to the removal capacity.The activated carboncontained phenolic functional groups atthe surface. The reaction between the phenolic functionalgroups on PCA and metal ion adsorbed H ions from thesolution, and the pH of the solution increased initially andthen decreased with decreased removal of metal ions.The increase in pH with the MCAs has a different explanation.The reaction between sodium acetate and metalions released Na ions, which came from a strong base,and increased the pH of the solution. The result indicatesthat the pH of the effluent is related to the removal of metalions.

4.2 Mechanism for the removal of Cu(II) ions

The specific surface area of PCA in this experiment was480 m2/g, and this was reduced to 300 m2/g after modificationby treatment with sodium acetate but the adsorptionincreased from 1.4 mg of Cu(II)/g to 3 mg of Cu(II)/g.The surface area was reduced from650 m2/g to 430 m2/g after modification, but increasedthe adsorption capacity from 6 mg of Cu(II)/g to 15 mgof Cu(II)/g It was an indication that the pore networkadsorption was not the only mechanism involved.In order to understand the mechanism underlying theprocess, an experiment was conducted in which a sampleof the column effluent was taken to measure the concentrationof Cu(II) and Na ions.

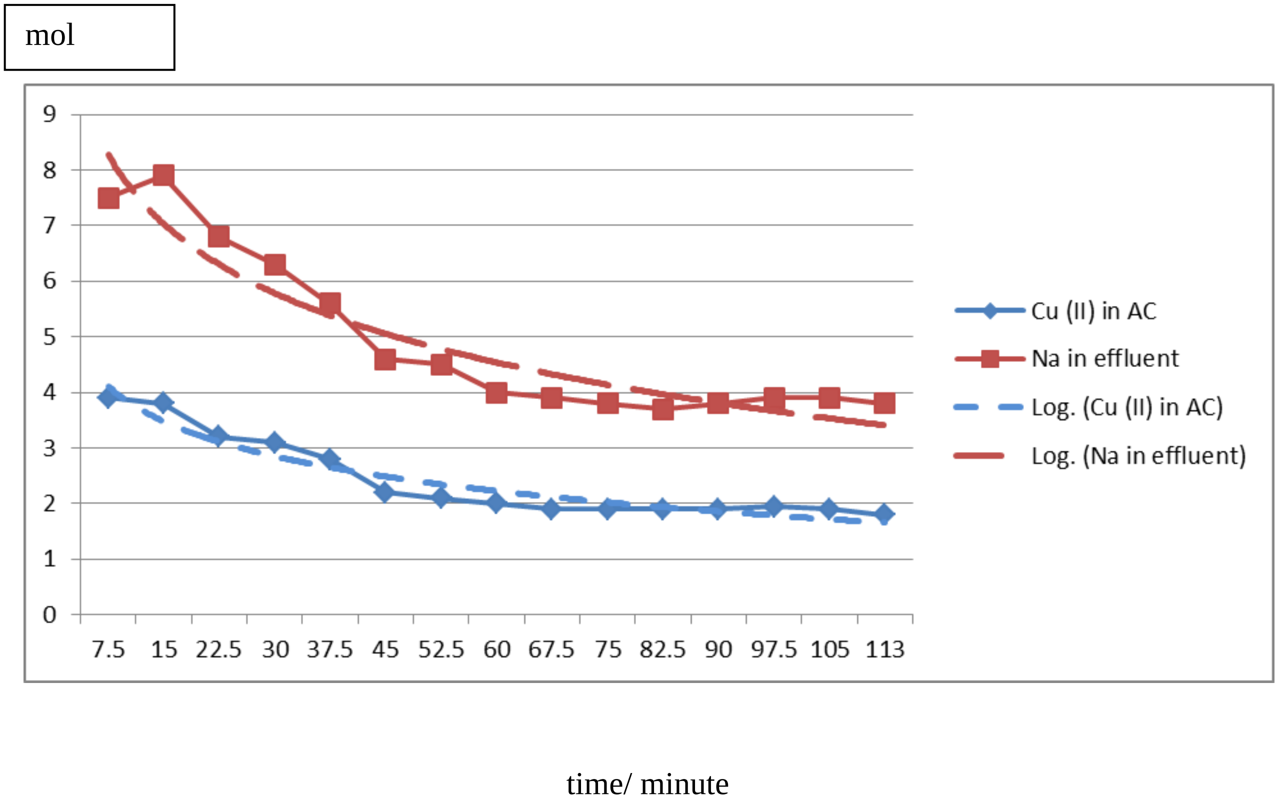

Figure 7: Ion exchange mechanism of Na and Cu(II) in MCA15.

As can be seen in Fig. 3, Naand Cu(II) ions have the same trends; Na ions in the effluentdecreased while Cu(II) adsorbed in the activated carbondecreased. There was 250 mg/l of Cu(II) ions in theinfluent, which was reduced to 5 mg/l in the effluent after7.5 min. The result was different for Na ions; 1 mg/l ofNa ions was found in the influent, which was increasedto 174 mg/l in the effluent.The number of Cu(II) ions removed from the solutionwas almost equivalent to the number of Na ions addedto the solution. From the following reaction, it can be seenthat the result agreed with calculations, where Cu(II) was3.85 mol and Na was 7.54 mol.

$2CH3COONa+CuSO4 \longrightarrow Cu(CH3COO)2 +NaSO4$ (1)

The hydrophobic groups were adsorbed onto the surfaceof activated carbon, while the ionic groups remained in thebulk solution and acted as a cationic exchanger. Similarly,in our experiment, the organic group was adsorbedonto the surface of the activated carbon and the Na ionacted as the cationic exchanger.

4.3 Regeneration of MCA15

Regeneration should be a part of the process of usingMCA in the process line. When a breakthrough occurred,certain chemicals flowed into the column to take theadsorbed Cu(II) ions from the MCA, which was laterreturned to service for another use. I used 0.7 M NaOHto take the Cu(II) ions from the activated carbon and torecover the Na ions at the surface functional contained 2550 mg/l of Cu(II) ion. In the second sample,groups. Fig. 4 plots the concentration of Cu(II) ions in the effluent of the regeneration process. In the first run, the effluentthe Cu(II) ions in the effluent decreased significantly. Theexperiment was stopped after 30 min because the amountof Cu(II) ions contained in the effluent became small.The end result of regeneration was 39 mg of Cu(II) ions,which is 87% of the Cu(II) ions adsorbed by MCA15.

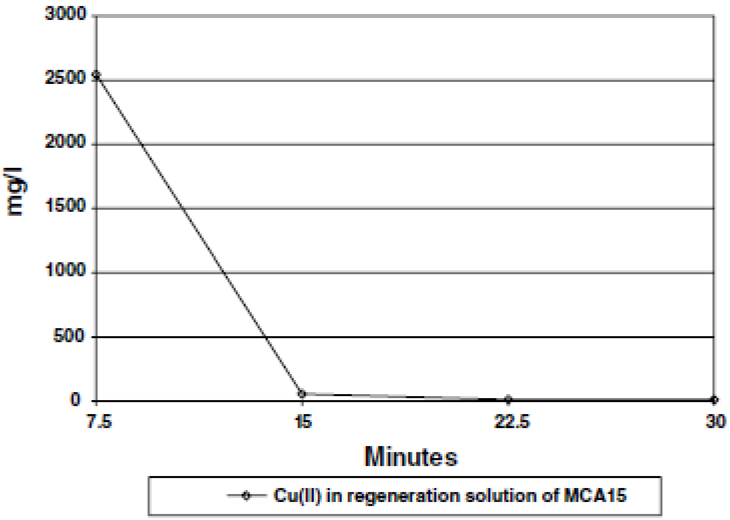

Figure 8: Cu(II) in effluent of regeneration process of MCA15.

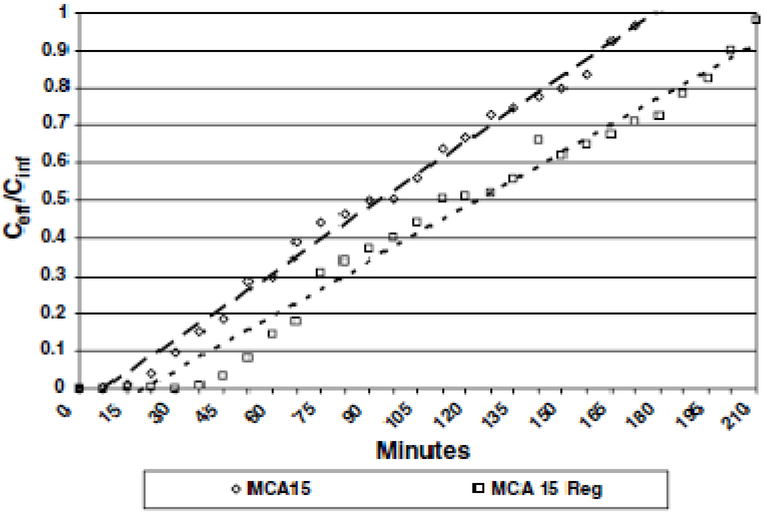

Figure 9:(II) ion removal using MCA15 and MCA15 Reg.

In Fig. 5, the Cu(II) ions in the effluent from the activatedcarbon after the regeneration of MCA15 (MCA15Reg) is plotted and compared with MCA15. Theadsorption by MCA15Reg was 60.1 mg of Cu(II), whichis an increase by about 1.5 times of MCA15 and 3 timesof PCA. The activated carbon contained surface functionalgroups that make a large contribution to metal ion adsorptiononto the activated carbon. The addition ofsodium acetate increased the number of functional groupson the activated carbon surface. In MCA15Reg, the Naions took the place of the Cu(II) ions that were adsorbedon the activated carbon surface. In this process, the Naions also react with other surface functional groups andthereby increase the number of functional sites on the activatedcarbon surface. This is the reason why the adsorptionby MCA15Reg was greater than that by MCA15.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

An experiment to remove Cu(II) ions from syntheticwastewater with MCA was conducted. The results showedthat modification of activated carbon using 15% sodiumacetate (MCA15) had a capacity greater than 3.0 mg ofCu(II)/g, while the capacity of PCA was only 1.4 mgCu(II)/g. The mechanism of removal was cationicexchange, which occurred because the Na ions act as cationicexchangers. After regeneration, the adsorption byMCA increased, from 45.1 mg of Cu(II) to 60.1 mg ofCu(II). This was because there were more Na ions on theactivated carbon reactive sites after regeneration.

5.2 Recommendation

The recommendation for this project is the effect of other parameter such as activation temperature should be investigated to determine the optimum condition for modification. There are a few other methods to modify activated carbon such as ammonization and evaporation in concentrated solution. Hope for the other method can be done in the future. Another recommendation is the BET and porosity analysis should be done for the strong evidence about the effect of modification. Adsorption study using different contaminant/pollutant should be done in order to make sure this method of modification is applicable or not the the those contaminant

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