APPLICATION OF LOCAL BIOMASS AS AN ADSORBENT FOR REMOVAL OF PHENOL FROM AQUOEUS SOLUTION

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I declare that this dissertation entitled *"Application of local biomass as an adsorbent for removal of phenol from aqueous solution"* is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....
Name : NURUL ILYANA BINTI ALI
Date :

Special Dedication of This Grateful Feeling to My…

Beloved mother;
Mdm. Rokiah binti Ahmad

Dearest friend;
Muhammad Safuan bin Othman

Understanding and helpful friends;

For Their Love, Support and Best Wishes.

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ABSTRACT

This paper shows a detailed study to observe the efficiency of banana peel and orange peel as a low cost adsorbent to remove phenol from aqueous solution. The banana and orange peel were used as biomass and obtained locally. The biomass initially was pre-treat into small particle and dried at 60^{o}C for 48 hours. There were three parameters studied in this paper which was the effect of adsorption time, effect of adsorbent dosage and effect of pH. From the experiment, it was found that the optimum adsorption time for banana peel as adsorbent was 240 minutes which equal to 4 hours; the optimum adsorbent dosage was 0.5g based on the higher adsorption capacity per unit mass of adsorbent and the optimum pH was in basic condition with pH 9 to 11. At this optimum condition, the phenol uptake was increase. As for orange peel, the maximum percentage of phenol removal was 24% at condition of initial concentration was 100mg/L; adsorption time was 240 minutes; adsorbent dosage was 0.5g and pH of solution is 11. The phenol uptake was analyzed using UV-Visible spectrophotometer. From the result, it was proven that banana peel and orange peel can be one type of low cost adsorbent but it also shows that banana peel was better in phenol removal compared to orange peel and this method can be applied in industrial wastewater.

ABSTRAK

Kajian ini menunjukkan tentang kajian lanjut untuk mengkaji keupayaan kulit pisang dan kulit oren sebagai salah satu penjerap harga rendah untuk menyingkirkan fenol dari larutan akues. Kulit pisang dan oren digunakan sebagai biojisim dan didapati di kawasan tempatan. Biojisim pada mulanya di pra-rawat kepada zarah yang kecil dan dikeringkan pada suhu 60^{o}C selama 48 jam. Terdapat tiga faktor penghad yang dikaji iaitu kesan masa penjerapan, kesan jumlah dos penjerap dan kesan pH. Daripada eksperimen yang dijalankan, telah didapati masa penjeraban terbaik untuk kulit pisang sebagai penjerap ialah 240 minit dimana bersamaan dengan 4 jam; dos penjerap terbaik ialah 0.5g berdasarkan kepada kapasiti penjerapan tertinggi setiap jisim penjerab dan pH terbaik ialah pada keadaan alkali dengan pH antara 9 hingga 11. Pada keadaan terbaik ini, kadar penyingkiran fenol meningkat. Untuk kulit oren sebagai penjerap, persen maksimum untuk penyingkiran fenol adalah sebanyak 24% pada keadaan kepekatan awal ialah 100mg/L; masa penjerapan ialah 240 minit; dos penjerap ialah 0.5g dan pH larutan ialah 11. Daripada hasil ujikaji, telah terbukti bahawa kulit pisang and kulit oren boleh menjadi salah satu jenis penjerap harga rendah tetapi ia juga menunjukkan bahawa kulit pisang adalah lebih baik untuk penyingkiran fenol berbanding dengan kulit pisang dan kaedah ini boleh diaplikasikan pada air buangan industri.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AC	Activated Carbon
CWO	Catalytic Wet Oxidation
CWAO	Catalytic Wet Air Oxidation
DIPE	Diisopropylether
DO	Dissolved Oxygen
EPA	Environment Protection Agency
HPLC	High Performance Liquid Chromatography
LCA	Low Cost Adsorbent
LED	Light Emitting Diodes
LSM	Lanthanum Strontium Manganite
MIBK	Methyl Isobutyl Ketone
RBC	Rotating Biological Contactor
TOC	Total Organic Carbon
WHO	World Health Organization

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Nowadays, phenols are widely used for the commercial production of a wide variety of resins, including phenolic resins, which are used as construction materials for automobiles and appliances, epoxy resins and adhesives, and polyamide for various applications (B. Ozkaya *et. al*., 2006). Phenol, a derivative of benzene, is an important raw material and/or product of chemical and allied industries (i.e., petrochemicals, oil refineries, plastics, leather, paint, pharmaceutical, steel industries, and pesticides) (V. C.Srivastava *et. al.*, 2006), These compounds are common contaminants in wastewater and suspected as toxic and carcinogenic. Therefore, the U.S. Environmental Protection Agency (Washington,D.C.) (U.S. EPA) has listed phenol and phenolic compounds on the list of priority pollutant which take 11^{th} place in the list of 129 chemicals (U. S. EPA, 1987). Chronic toxic effects resulting from phenols reported in humans include vomiting, difficulty in swallowing, anorexia, liver and kidney damage, headaches, fainting, and other mental disturbances. Phenol toxicity and difficult biodegradability removal has led to the setting up of rigid limits on the acceptable level of phenol in the environment. While the Ministry of Environment and Forests of New Delhi, India has set a maximum concentration level of 1.0 mg/L of phenol in industrial effluents for safe discharge to surface waters, the

World Health Organization (WHO) recommends the permissible phenolic concentration of 0.001 mg/L in potable waters (World Health Organization, 1963).

Various treatment technologies for the removal of phenol from wastewater are available such as adsorption (A. A. M. Daifullah, *et. al*., 1998), photodegradation (C. Wu, *et. al.*, 2001) flocculation (T. A. Ozbelge, *et. al*., 2002), chemical oxidation (V. Kavita, *et. al.*, 2004), biological process (K. Karim, *et. al.*, 2001) , etc. Biological process is particularly suited to wastewater containing small amount of phenol. Oxidation is used when phenol concentration in wastewater is very high. In coagulation and flocculation process, large amount of sludge is generated which may cause disposal problems. Among them, adsorption method is considered to be the best, effective, low cost and most frequently used method for removal of phenol from wastewater (P. K. Asthana, *et. al*., 1994). Many types of sorbents based on low cost and naturally occurring adsorbents had been used such as wheat straw (T. Robinson, *et. al*., 2002), sawdust (V.K. Garg, *et. al*., 2004), wheat shells (Y. Bulut, *et. al*., 2007,) wheat bran (M. T Sulak, *et. al*., 2006), and hen feathers (A. Mittal, *et. al*., 2007). Banana peel and orange peel are one type of low cost agricultural by-products. It is useful as a medium or adsorbent to remove phenol and phenolic compounds in wastewater which are high toxicity and can affect our environment.

In this study, the adsorption of phenol using banana peel and orange waste was investigated due to easily available in large quantities and low cost agricultural waste residue which could represent as an economically source of biosorbent for removal of phenol in wastewater.

1.2 Problem statement

Phenolic compounds which contain high amount of phenol are generated from petroleum and petrochemical, coal conversion and phenol-producing industries, are common contaminants in wastewater and suspected as toxic and carcinogenic (A. I Mustafa, *et. al.*, 2008). Therefore, it is considered necessary to remove phenol from industrial effluents before it can be discharged to the environment. Many methods can be used to remove this compound from wastewater but the most effective, frequently used and valuable method is adsorption.

Adsorption is a well-known equilibrium separation process and an effective method for water decontamination applications. Adsorption has been found to be advanced to other techniques for water reuse in terms of initial cost, flexibility and simplicity of design and operation also insensitivity to toxic pollutants (Z. Aksu, *et. al*., 2001). The most popular and widely used adsorbent material for this treatment is activated carbon (A. Dabrowski, *et. al*., 2005). However, due to high initial cost and the need for a costly regeneration system make the activated carbon less economically feasible as excellent adsorbent (O. Aktas, *et. al*., 2007). Therefore, adsorbent based on low cost agriculture by-products are being use as an alternative adsorbents that have been tested broadly.

Banana peel and orange waste is one type of low cost agriculture by-products adsorbent for removal of phenol in wastewater that has been studied previously. This source for adsorbent is an abundant and low cost agricultural waste residue and is easily available in large quantities (M. Achak, *et. al*., 2009). This is the mainly reason why banana peel is the lowest cost adsorbent that has been considered before.

1.3 Objective

The purpose of doing this study is to achieve the objective which is to study the efficiency of banana peel and orange waste as a low cost adsorbent and also to study the comparison of the adsorbents in adsorption of phenol from aqueous solution.

1.4 Scope of study

In order to achieve the objectives if this experiment, three types of parameters has been identified which is effect in adsorption time, adsorbent dosage, and pH of solution.

1.5 Rational and significance

The removal of phenol from wastewater is necessary due to environmental problems and cancer risks. This study can ensure the best method to remove phenol and also to show that banana peel and orange waste can be low cost adsorbents based on economical reasons availability of agricultural waste.

CHAPTER 2

LITERATURE REVIEW

2.1 Adsorption

2.1.1 Definition

Adsorption is the accumulation of atoms or molecules on the surface of a material. This process creates a film of the adsorbate which is the molecules or atoms being accumulated on the adsorbent's surface. In simple words, adsorption means the collection of a substance onto the surface of adsorbent solids. It is a removal process where certain particles are bound to an adsorbents particle surface by either chemical or physical attraction. Usually the amount adsorbed is only a fraction of a monolayer. Thus to adsorb a substantial amount of material, the adsorbent must have a large specific surface area. The specific surface area of typical adsorbents usually ranges from 0.1 to 1.0 km^2/kg.

Adsorption is caused by a type of Van der Waals Force which exists between molecules. The force acts in a similar way to gravitational forces between planets. These sources are extremely short ranged and therefore sensitive to the distance between the carbon surface and the adsorbate molecule. They are also additives,

meaning the adsorption force is the sum of all interactions between all the atoms. The short range and additive nature of these forces results in activated carbon having the strongest physical adsorption forces of any known material. Some common examples of adsorption are the carbon canister to adsorb gasoline vapor in automobile fuel tanks, silica gel packets to adsorb moisture from packaged electronic or optical equipment, and carbon filter to deodorize drinking water.

Adsorption process can happen in two phase which is gas phase and liquid phase. In gas phase adsorption, a condensation process where the adsorption forces condense the molecules from the bulk phase within the pores of the activated carbon. The driving force for adsorption is the ratio of the partial pressure and the vapor pressure of the compound. The adsorption capacity for non-polar organics increases with the boiling point, molecular weight and concentration of the air contaminant. Low molecular weight which is less than 50 or highly polar compounds such as formaldehyde, methane, ethanol, etc., will not be readily adsorbed at low concentrations. In liquid phase adsorption process, the molecules go from the bulk phase to being adsorbed in the pores in a semi-liquid state. The driving force for adsorption is the ratio of the concentration to the solubility of the compound. In general, the adsorbability of a compound increases with:

- Increasing molecular weight
- A higher number of functional groups such as double bonds or halogen compounds
- Increasing the polarisability of the molecule. This is related to electron clouds of the molecule

From the previous study, adsorption is one of the most effective processes of advanced wastewater treatment, which many industries employ to reduce hazardous organic and inorganic wastes in effluents (M. Ahmaruzzaman *et. al.,* 2005). Adsorption is considered to be the most potential method due to its high efficiency and ability to separate wide range of chemical compounds (A.Mittal *et. al.,* 2005)

Removal of phenolic compounds from wastewater using adsorption process has been studied before to discover the mechanism and kinetics of the process. It is important to know what parameters that can affect the adsorption process in order to find the most efficient rate of sorption.

2.1.2 Adsorbent

An adsorbent is a substance which is usually porous in nature and has a higher surface area that can adsorb or cause to accumulate substances onto its surface by intermolecular force. In wastewater treatment process, many types of adsorbents have been used to remove contaminants substances that can give toxicity to environment. The most popular and widely used adsorbent material for wastewater treatment is activated carbon because of its higher surface area per unit mass an exhibits a high adsorption capacity for phenolic compounds (H. Cerifi *et. al.*, 2009). The usage of activated carbon as an adsorbent for industrial wastewater treatment is capital-intensive and has a several other problems, such as (1) regeneration of activated carbon, (2) intraparticle resistance in adsorption processes in practice, and (3) high cost of manufacture (M. Ahmaruzzaman *et. al.*,2005). Therefore, due to high cost of regeneration system make this type of adsorbents less cost-effectively (M. Achak *et. al.*, 2009). In order to minimize the cost of treatment process, low cost adsorbents will be used as major materials to remove phenolic compounds, heavy metals and other contaminants substances. The usage of agricultural by-products as highly prior for choosing an adsorbent is because of the economical reasons and green technology courage around the world. Below are the lists of Low Cost Adsorbents (LCAs) for phenolic compound removal that have been studied before:

Table 2.1: List of Low Cost Adsorbents (LCAs) for removal of phenolic compound from wastewater

Adsorbent	Adsorbate	References
Banana peel	Phenolic compounds	M. Achak *et al*., (2009)
Beet pulp	Phenol	Dursun *et al*., (2005)
Coconut shell	Phenol	A.T. Mohd Din (2008)
Date pits	Phenol	Banat *et al*., (2004)
Dried sewage sludge	Phenol	Thawornchaisit *et al.*, (2007)
Paper mill sludge	Phenol	Calace *et al*., (2002)
Tamarind nut shell	Phenol	Goud *et al*., (2005)
Water hyacinth ash	Phenol	M.T. Uddin *et al*., (2007)
Palm pith carbon	2,4-dichlorophenol	Sathishkumar *et al*., (2007)
Industrial waste	Bromophenols	Bhatnagar *et al*., (2007)

2.1.3 Adsorption process

In the few years, many researchers have been done to prove that the kinetics studies have been very helpful to determine the process of adsorption. There is several equation of kinetics for adsorption can be used. It is showed that the results and graph plotted are almost all precise, undesirable and always can be interpreted easily. The most important for adsorption process to determine the mechanism of sorption for the design purpose. Generally, the adsorption dynamics is accepted to consist of the three consecutive steps:

i. Transport of adsorbate molecules from the bulk solution to the adsorbent external surface through the boundary layer diffusion.
ii. Diffusion of the adsorbate from the external surface into the pore of the adsorbent.
iii. Adsorption of the adsorbate on the active sites on the internal surface of the pores.

As the general, adsorbability of a compound increased with the increasing molecular weight, a higher number of functional groups such as double bonds or halogen compounds and also increasing polarisability of the molecule. There are many studies conducted, proven that the boundary layer diffusion is the rate controlling steps in the system by dilute concentration of adsorbate, poor mixing, and small particle size of adsorbent. In addition, the inter particle diffusion controls the rate of adsorption in system by high concentrations of adsorbate, vigorous mixing and large particle size of adsorbent.

Usually, the layer diffusion is dominant at the beginning of adsorption during the initial removal, and then the rate of adsorption is regularly controlled by the intraparticle diffusion as the capacity of adsorbate has loaded the external surface of adsorbent. From the last step, adsorption is very rapid to be compare with the first two steps. For that reason, it can be considered that the overall rate of adsorption is controlled by either the boundary layer or pore diffusion, or combining both.

Based on the previous study, the amount of phenol adsorbed at equilibrium, q_e was calculated from the mass balance equation (M. Achak *et al*., 2009):

$$q_e = \frac{(C_0 - C_{eq})V}{X} \qquad 2.1$$

Where q_e is the amount of phenol adsorbed (mg/g) at time, C_0 is the initial phenol concentration in liquid phase (mg/L), C_{eq} represents the phenol equilibrium concentration (mg/L), V is the volume of solution used (L) and X is the mass of adsorbent used (g).

2.2 Phenol

In organic chemistry, phenols or phenolics are a class of chemical compounds that consists of a hydroxyl group (-OH) bonded directly to an aromatic hydrocarbon group. Although similar to alcohols, phenols have unique properties and not classified as alcohols due to the hydroxyl group is not bonded to a saturated carbon atom. Phenols can have two or more hydroxyl groups bonded to aromatic rings in the same molecule. The simplest of phenols class is phenol which also known as carbolic acid. Its chemical formula is C_6H_5OH and its structure is that of a hydroxyl group (-OH) bonded to a phenyl ring, making it an aromatic compound. Phenol is a white crystalline solid at room temperature and normal atmospheric pressure. It has a burning taste and a distinctive odor.

Phenol are usually used in commercial production of a wide variety of resins which are used as construction materials for automobiles and appliances, epoxy resins adhesive, and polyamide for various application. Phenol also is an important raw material and also a product of chemical and allied industries such as petrochemicals, oil refineries, plastic, paint, steel industries and also in production of pesticides. Phenol is also a versatile precursor to a large collection of drugs, most notably aspirin but also many herbicides and pharmaceuticals. Phenol is the preferred chemical for embalming bodies for study because of its ability to preserve tissues for extended periods of time. However, formaldehyde is usually preferred over phenol for embalming with intent of public viewing because of phenol's tendency to turn tissues an unpleasant bleach-white color. Phenol is also used in the preparation of cosmetics including sunscreens, hair dyes, and skin lightening preparations. In cosmetic surgery, phenol serves as an exfoliant. It is also used in phenolization, a surgical procedure used to treat an ingrown nail, in which it is applied to the nail bed to prevent regrowth of nails. 5% Phenol is sometimes injected near a sensory nerve in order to temporarily (up to a year) stop it from transmitting impulses in some intractable cases of chronic neuropathic pain.

2.2.1 Toxicology effect of phenol

Phenol and its vapor are corrosive to the eyes, the skin, and the respiratory tract. Repeated or prolonged skin contact with phenol may cause dermatitis, or even second and third-degree burns due to phenol's caustic and defatting properties. Inhalation of phenol vapor may cause lung edema. The substance may cause harmful effects on the central nervous system and heart, resulting in dysrhythmia, seizures, and coma. The kidneys may be affected as well. Exposure may result in death and the effects may be delayed. Long-term or repeated exposure of the substance may have harmful effects on the liver and kidneys. There is no evidence to believe that phenol causes cancer in humans. Besides its hydrophobic effects, another mechanism for the toxicity of phenol may be the formation of phenoxyl radicals.

Chemical burns from skin exposures can be decontaminated by washing with polyethylene glycol, isopropyl alcohol, or perhaps even copious amounts of water. Removal of contaminated clothing is required, as well as immediate hospital treatment for large splashes. This is particularly important if the phenol is mixed with chloroform which commonly-used mixture in molecular biology for DNA & RNA purification from proteins.

Phenols are considered to be hazardous wastes, which are released into aquatic environment by industries such as petroleum refineries, petrochemical, pharmaceutical, fertilizer, and dye industries have been reported in hazardous sites. The content of phenols in industrial wastewater in about 200-2000mg/L is usually higher than standard limits in Environmental Quality Act 1974 which is less than 0.5mg/L (M. Ahmaruzzaman *et. al.*,2005). The maximum concentration of phenols in drinking water is given as 0.5µg dm^{-3} by European Union (A. Y. Dursun. e*t. al.,* 2005; N. Calace *et. al.,* 2002). They exist in different concentrations in wastewater originating from cooking, synthetic rubber, plastics, paper, oil, etc. Solutions of phenol are corrosive to the skin and eyes. It also can irritate the respiratory area when vaporized. Phenol is usually exposed to general population by inhalation. Chronic

effects due to phenols reported in humans include vomiting, difficulty in swallowing, anorexia, liver and kidney damage, headache, fainting and other mental disturbances. In general, the introduction of phenolic compounds in the environment or degradation of these substances means the appearance of phenol and its derivatives in the environment (H. Cerifi *et. al.*, 2009).

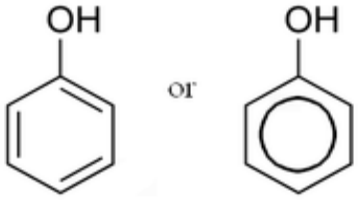

Figure2. 1: Chemical structure of phenol

2.3 Ultraviolet visible (UV-Vis) spectroscopy

Ultraviolet-visible spectroscopy or ultraviolet-visible spectrophotometry (UV-Vis) refers to absorption spectroscopy in the UV-visible spectral region. This means it uses light in the visible and adjacent ranges. The absorption in the visible range directly affects the perceived color of the chemicals involved. In this region of the electromagnetic spectrum, molecules undergo electronic transitions. This technique is complementary to fluorescence spectroscopy, in that fluorescence deals with transitions from the excited state to the ground state, while absorption measures transitions from the ground state to the excited state.

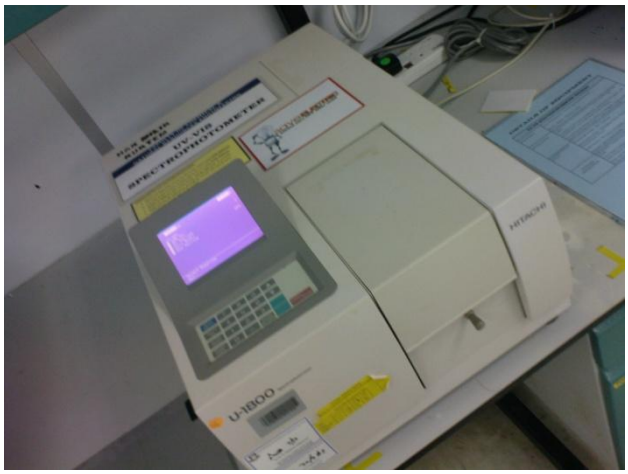

Figure 2.2: UV Visible spectrophotometer

UV/Vis spectroscopy is routinely used in the quantitative determination of solutions of transition metal ions and highly conjugated organic compounds.

1. Solutions of transition metal ions can be coloured (i.e., absorb visible light) because d electrons within the metal atoms can be excited from one electronic state to another. The colour of metal ion solutions is strongly affected by the presence of other species, such as certain anions or ligands. For instance, the colour of a dilute solution of copper sulfate is a very light blue; adding ammonia intensifies the colour and changes the wavelength of maximum absorption (λ_{max}).

2. Organic compounds, especially those with a high degree of conjugation, also absorb light in the UV or visible regions of the electromagnetic spectrum. The solvents for these determinations are often water for water soluble compounds, or ethanol for organic-soluble compounds. Organic solvents may have significant UV absorption; not all solvents are suitable for use in UV spectroscopy. Ethanol absorbs very weakly at most wavelengths. Solvent polarity and pH can affect the absorption spectrum of an organic compound. Tyrosine, for example, increases in absorption maxima and molar extinction coefficient when pH increases from 6 to 13 or when solvent polarity decreases.

3. While charge transfer complexes also give rise to colors, the colors are often too intense to be used for quantitative measurement.

The Beer-Lambert law states that the absorbance of a solution is directly proportional to the concentration of the absorbing species in the solution and the path length. Thus, for a fixed path length, UV/VIS spectroscopy can be used to determine the concentration of the absorber in a solution. It is necessary to know how quickly the absorbance changes with concentration. This can be determined from a calibration curve.

A UV/Vis spectrophotometer may be used as a detector for HPLC. The presence of an analyte gives a response which can be assumed to be proportional to the concentration. For accurate results, the instrument's response to the analyte in the unknown should be compared with the response to a standard; this is very similar to the use of calibration curves. The response such as peak height for a particular concentration is known as the response factor.

The basic parts of a spectrophotometer are a light source, a holder for the sample, a diffraction grating or monochromator to separate the different wavelengths of light, and a detector. The radiation source is often a Tungsten filament in range 300 to 2500 nm, a deuterium arc lamp which is continuous over the ultraviolet region which is 190 to 400 nm, and more recently light emitting diodes (LED) and Xenon Arc Lamps for the visible wavelengths. The detector is typically a photodiode or a CCD. Photodiodes are used with monochromators, which filter the light so that only light of a single wavelength reaches the detector. Diffraction gratings are used with CCDs, which collects light of different wavelengths on different pixels.

A spectrophotometer can be either single beam or double beam. In a single beam instrument such as the Spectronic 20, all of the light passes through the sample cell. Io must be measured by removing the sample. This was the earliest design, but is still in common use in both teaching and industrial labs.

In a double-beam instrument, the light is split into two beams before it reaches the sample. One beam is used as the reference; the other beam passes through the sample. Some double-beam instruments have two detectors, and the sample and reference beam are measured at the same time. In other instruments, the two beams pass through a beam chopper, which blocks one beam at a time. The detector alternates between measuring the sample beam and the reference beam.

Samples for UV/Vis spectrophotometry are most often liquids, although the absorbance of gases and even of solids can also be measured. Samples are typically placed in a transparent cell, known as a cuvette. Cuvettes are typically rectangular in shape, commonly with an internal width of 1 cm. Test tubes can also be used as cuvettes in some instruments. The type of sample container used must allow radiation to pass over the spectral region of interest. The most widely applicable cuvettes are made of high quality fused silica or quartz glass because these are transparent throughout the UV, visible and near infrared regions. Glass and plastic cuvettes are also common, although glass and most plastics absorb in the UV, which limits their usefulness to visible wavelengths.

2.4 Treatment technology for phenol removal

Various treatment technologies for the removal of phenol from wastewater are available such as adsorption, extraction, ozonation, flocculation, chemical oxidation and biological process.

Table 2.2: List of separation technique for phenol

Technique	Type of reactor	References
Adsorption using activated carbon	Fixed bed column with activated carbon	H. G. Franck *et. al.*, (1989)
Membrane extraction	Membrane module	W. Kujawski *et. al.*, (2003)
Wet air oxidation	Bubble column	S. K. Bhargava *et. al.*, (2006)
Ozonation	Bubble column	O. Chedeville *et. al.*, (2007)
Biological degradation	Slurry or fixed bed	P. Saravanan *et. al.*, (2008) K. Vidya Shetty *et. al.*, (2007)

2.4.1 Separation by extraction

Several organic solvents, such as hydrocarbons and oxygenated compounds, may allow the extraction of phenol from water. Among others, n-hexane and cyclohexane, benzene, toluene, ethyl benzene, cumene, acetate esters such as ethyl acetate, isopropyl acetate, di-isopropyl ether, methyl-iso-butyl ketone (R. Alvarez Gonzalez, *et. al.*,1986; R.T.P. Pinto, *et. al.*,2005; D.C. Greminger, *et. al.*,1982), as well as more complex molecules such as n-octylpyrrolidone (Z. Li. M, *et. al.*, 2004).

Phenol-containing water from the production of phenol by the cumene process, i.e., the liquid arising from caustic washing and distillation of crude acetone

and that arises from caustic washing of cumene to be recycled (W. Jordan, *et. al.*, 2002; R.J. Schmidt, *et. al.*, 2005), which can contain 1–3% phenol, are mixed and freed by extraction from most of their phenol content. Cumene produced by the process is used as extracting agent in a counter-current extraction column. The cumene solvent from the top of the extraction column is then scrubbed of phenol in a counter-current caustic scrubbing column. The resulting sodium phenate solution then flows to the sodium phenate tank. The lean cumene is recycled to the extraction column. The extraction column bottom is one of the net wastewater streams from the phenol unit. In this way phenol is removed, depending on the process, down to a residual concentration of 20–500 mg/l. The remaining phenol is removed in the biological purification stage in a sewage treatment plant.

The so-called “Phenosovan” extraction process, from Lurgi, is used to remove phenol from waters in gasification plants (R.H. Matjie, *et. al.*, 2007) as well as in coke oven and carbonization plants, in the phenol industry, and in coal hydrogenation plants (G. Hochgesand, *et. al*,. 2002). The filtered and cooled phenolic effluent is treated counter-currently with a suitable solvent, usually diisopropylether (DIPE) in a multistage extractor. The extract is separated by fractional distillation into pure DIPE solvent as overhead product and crude phenol as bottom product, while a water-containing azeotrope can also be recovered as a lateral stream and recycled back. The solvent is recycled to the extractor. The raffinate still contains a small amount of solvent which is recovered by stripping with recycled gas. The solvent is then removed from the gas by absorption in cooled and recycled crude phenols, from which it is subsequently recovered in the stripping section of the fractionators. The Phenosolvan process can be operated with different feedstock, different solvents or solvent mixtures sush as benzene and DIPE or DIPE plus methyl-isobutylketone, MIBK and different solvent recovery systems such as steam, gas, or ammonia stripping. All steam volatile phenols and neutral oils can be recovered almost completely, but only partial recovery of dihydric phenols is possible. If large gas condensate flows must be dephenolized, extraction must be performed in mixer settlers, exhibiting high stage efficiencies. Lower flow rates can

be treated in extraction columns by using many stages to compensate for low efficiency.

2.4.2 Catalytic wet air oxidation (CWAO)

Considerable amount of research has been performed on WO catalysts to overcome the aforementioned costly, high-pressure, energy-intensive conditions. The number of different industrial waste/process streams requiring organics removal and the diversity of organic and inorganic compounds present in these streams has resulted in the investigation of a wide range of homogeneous and heterogeneous catalysts over the last three decades.

Catalytic wet air oxidation of phenol has been the object of many investigations in recent years. These studies have also been reviewed recently (S.K. Bhargava, *et. al.*, 2006; F. Luck, *et. al.*, 1999; F. Luck, 1996) Homogeneous catalysts for CWAO are usually transition metal cations, such as Cu and Fe ions. Industrial homogenous CWAO processes have been developed such as the Ciba-Geigy/Garnit process working at high temperature, and the LOPROX Bayer process working with oxygen below 200 $^{\circ}$C in the presence of iron ions. Common two-phase reactor types used in homogeneous CWO include bubble columns, jet-agitated reactors, and mechanically stirred reactor vessels (F. Luck, *et. al.*, 1999)

For practical reasons, solid catalysts are more useful to avoid the need of a separation step of the catalyst, and pollution of the waste. Most of the active catalysts proposed for CWAO or phenol are solids containing either noble metals (Pt, Ru) or transition metal cations (Cu, Co, Mn, Fe) as the active redox phases. Frequently, such active phases are supported on alumina or carbon carriers and may contain ceria

additives. Activated carbon may also act as a catalyst although it may be consumed by oxidation. Typical reaction conditions can allow phenol conversion around 90%-95%.

One of the most active catalysts that have been developed for CWO of phenol, in terms of TOC removal, is a $PtxAg_1{-}x\text{-}MnO_2/CeO_2$ catalyst that was developed by Hamoudi *et. al*., (2002), Polymeric products deposited on the catalyst was found to deactivate this and several other catalysts.

Catalysts containing Mn and Ce were also found very active by Chen *et al*. (2001), who reported that the high activity of this Mn- Ce-O catalyst is presumably due to the following: (i) improved oxygen storage capacity, (ii) improved oxygen mobility on the surface of the catalyst, and (iii) an electron-rich surface, which may be very important in the activation of adsorbed oxygen. Solid compounds containing manganese, such as the commercial perovskite lanthanum strontium manganite (LSM) also show interesting properties in phenol CWO (S. Berardinelli, 2007).

Reaction pathways for the CWO of phenol have been studied by several researchers. Many different intermediates form from the CWO of phenol on various catalysts. These intermediates can have a significant effect on phenol TOC conversion. In recent studies, attention has been paid in the evolution of eco-toxicity during WAO and CWAO of phenol and of other water pollutants. A significant increase of toxicity has been observed during the early stages of phenol oxidation (A. Santos, *et. al.,* 2004) caused by the formation of hydroquinone and p-benzoquinone as intermediates, the former showing the highest toxicity. Furthermore, synergistic effects, giving rise to a significant increase of toxicity, have been observed. These effects derive from the interactions among copper leached from the catalyst usually a commercial copper based catalyst in this case and catechol, hydroquinone, and p-benzoquinone and demand that close attention be paid to this potential problem in

catalytic wet oxidation. Acetic acid is formed as a final intermediate during CWO of phenol using several different catalysts. Because acetic acid is a difficult compound to remove via CWO, it has a negative impact on phenol TOC conversions.

First order in phenol has usually been obtained together with 0.5 orders in oxygen. A relevant problem in heterogeneous CWAO is associated to the leaching of the active metal species that can produce a heterogeneous or homogeneous catalysis. Leaching, however, pollutes the wastewater and results in the progressive loss of catalytic activity of the solid catalyst. This phenomenon is evident mostly for supported transition metal catalysts. The kinetics of phenol wet oxidation over noble metal catalysts has been investigated by Cybulski and Trawczyn´ ski (A. Cybulski, *et. al.*, 2004). According to this study, oxidation of phenol proceeds substantially via two routes which is directly to carbon dioxide and through intermediates which are difficult to oxidize over the catalysts studied.

According to Levec and Pintar (J. Levec, *et. al., 2007*) , that reviewed very recently process conditions for industrial CWAO processes, the catalyst must be tailored for each particular application and made of inexpensive materials. Oxides of Zr, Ce, and Ti may be used as stable supports. Metal oxide catalysts are very active but unstable (dissolution). In order to reduce leaching, the catalytically active compounds have to be incorporated into a lattice of catalyst support. If this is not feasible, the catalytic active phase should consist of precious metals. In fact, existing commercial processes (J. Levec, *et. al.*, 2007), employ supported noble metal catalysts. It would be advantageous to design a catalyst that can be employed for the treatment in single-pass reactors with a minimum lifetime over 500 h. To improve the performances, a step constituted by an AC adsorbing bed, where the organics are removed from the wastewater stream and pre-concentrated, may be useful, as in the CALIPHOX process, as shown in Figure 2.3. In any case, the primary goal of CWAO should be to convert organics into products more amenable to biological treatment; complete oxidation may be too expensive.

Although several academic investigations are performed in slurry stirred tank reactors, industrial application will need trickle bed, bubble slurry column, and bubble fixed bed (monolith) or three-phase fluidized bed reactors, to allow easy separation of the catalyst and continuous operation.

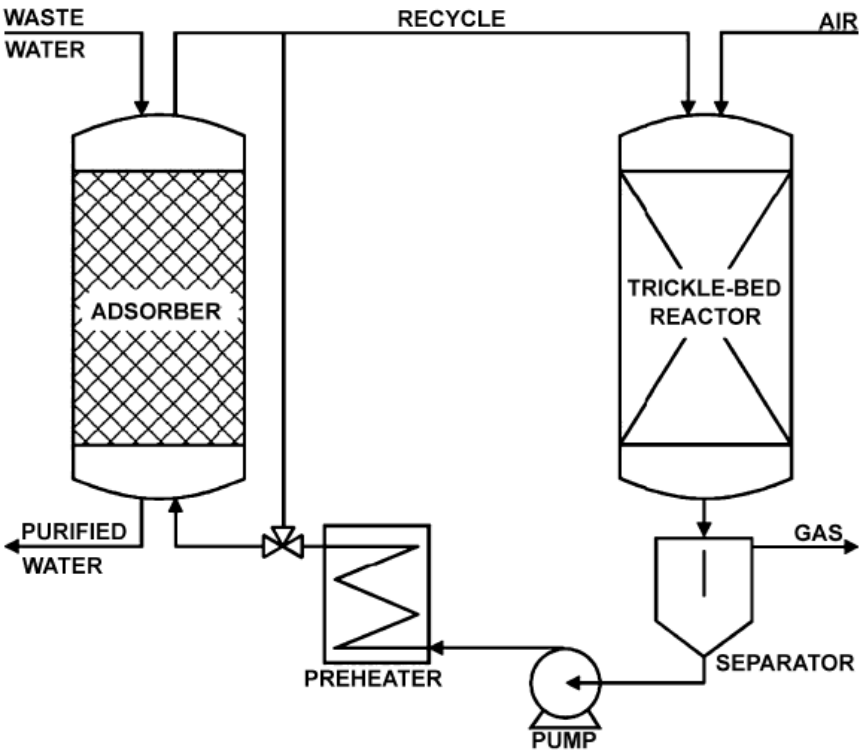

Figure 2.3: Schematic drawing of the CALIPHOX process for catalytic liquid-phase oxidation of organic pollutants with an adsorber unit for pre-concentration. (J. Levec *et. al.*, 2007)

2.4.3 Biological degradation

Aerobic biodegradation of many classes of aromatic compounds is common and proceeds through the key intermediate, catechol. Many microbial strains capable of degrading phenol have been cited such as *Pseudomonas putida, Pseudomonas fluoroescens, Acinetobacter, Trichosporon cutaneum* and *Candida tropicalis*. Most of the cultures tested are capable of degrading phenol at low concentrations.

However phenol is toxic to most types of microorganisms at sufficiently high concentration and can be a growth rate inhibitory to even those species, which have the metabolic capability of using it as a substrate for growth. So, for achieving satisfactory performance, phenol concentration needs to be maintained below toxic limits and acclimatization of organism to the wastewater environment is required.

Most of these studies have involved single microbial species which may have limitations in field application due to the presence of different contaminants in the waste. The physical contact among co-aggregative cells can lead to a combined metabolic advantage over single cells, favour mutualistic relationship for biofilm growth, and facilitate the flow of diffusible signals. Therefore, co-aggregates may enable the proper spatial location of different species and facilitate the opportunity to form essential partnerships within the growing biofilms, thus influencing the overall development of the complex microbial community. The effect of co-aggregation of two bacterial strains, *Propioniferax-like PG-02* and *Comamonas sp. PG- 08* on phenol degradation and aerobic granulation was investigated by Lond Jang *et. al.*,(2006). In batch, the co-culture degraded phenol at an initial concentration of 250 mg/l, faster than each strain separately. The biodegradation of phenol by a mixed microbial culture, isolated from a sewage treatment plant, was investigated recently by Saravanan *et. al.*,(2008).

Also fungi strains have been reported to be active in phenol biodegradation. *Nocardia hydrocarbonoxydans*, actinomycetes, was found to effectively degrade phenol, to be resistant to contamination and to have higher inhibitory concentration level, as compared to many microbial species degrading phenol. The continuous aerobic biodegradation of phenol in synthetic wastewater was carried out using *N. hydrocarbonoxydans* immobilized over glass beads packed between the plates in a pulsed plate bioreactor at a frequency of pulsation of 0.5 s^{-1} and amplitude of 4.7cm (K. V. Shetty, *et. al.,* 2007).

The time taken to reach steady state has increased with increase in dilution rate and influent phenol concentration. It was found that, as the dilution rate is increased, the percentage degradation has decreased. Steady state percentage degradation was also reduced with increased influent phenol concentration. Almost 100% degradation of 300 and 500ppm influent phenol could be achieved at a dilution rate of 0.4094 h^{-1} and more than 99% degradation could be achieved with higher dilution rates. At a higher dilution rate of 1.0235 h^{-1} and at concentrations of 800 and 900ppm the percentage degradation has reduced to around 94% and 93%, respectively.

The attached biomass dry weight, biofilm thickness and biofilm density at steady state were influenced by influent phenol concentration and dilution rate.

A recent study took into consideration the behavior of *Fusarium sp*. in the detoxification of phenol in the effluents (W. Cai, *et. al.,* 2007). It was found active and retained catalytic activity in a wide range of pH 3–8.8 and temperature (30–50 $^{\circ}C$), although the activity is decreased by the presence of mineral salts. Most of the studies have involved single microbial or fungi species. The activated sludge is considered as a natural microbial consortium and appears as a more attractive

solution because of its various advantages (J.S. Melo, *et. al.*, 2007; J.N.T. D'Souza, *et. al.,* 1999), and is largely used in wastewater purification processes. Activated sludge acclimatized to 400ppm phenol was used for the biodegradation of phenol in a batch reactor system and a Rotating Biological Contactor (RBC). Phenol degradation in the batch reactor was studied in relation to supply of oxygen, in addition to the effect of biomass concentration. An aeration pump and oxygen concentrator was used to supply oxygen.

It was confirmed that the performance of system improved with increased availability of oxygen, as determined from the phenol degradation rate. Alternatively increasing stirring speed proportionally, increased the mass transfer coefficient of oxygen and also resulted in improved phenol degradation. However, in all the above cases the dissolved oxygen (DO) was zero in the presence of phenol. Studies using the RBC led to amelioration/improvement in DO levels, thus overcoming the limitations of oxygen supply to the process during phenol degradation in the batch mode.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The purpose of this study is to understand and analyzed result according to the ability of banana peel and orange peel to remove phenol from aqueous solution and to study the effect of contact time, adsorbent dosage and initial pH to adsorption of phenol. The method use for this experiment was according to previous study done by M. Achak *et al*., 2009. The experiment was conducted start from the preparation of adsorbent of banana and orange peel which was randomly collected. Then, wash thoroughly with water for several times to remove earthy matter and all the dirt particles, cut, dried, grind to obtain a fine powder and then it was stored at dry places. Next step is preparing the phenol stock solution. The phenol stock solution is prepared by dissolving crystal phenol in distilled water. This study was continued with the experiment to investigate the optimum condition for removing phenol from aqueous solution with parameter of adsorption time, dosage of adsorbent and initial pH. Lastly, the sample is analyzed by using UV-Visible spectrophotometer with wavelength of 725nm.

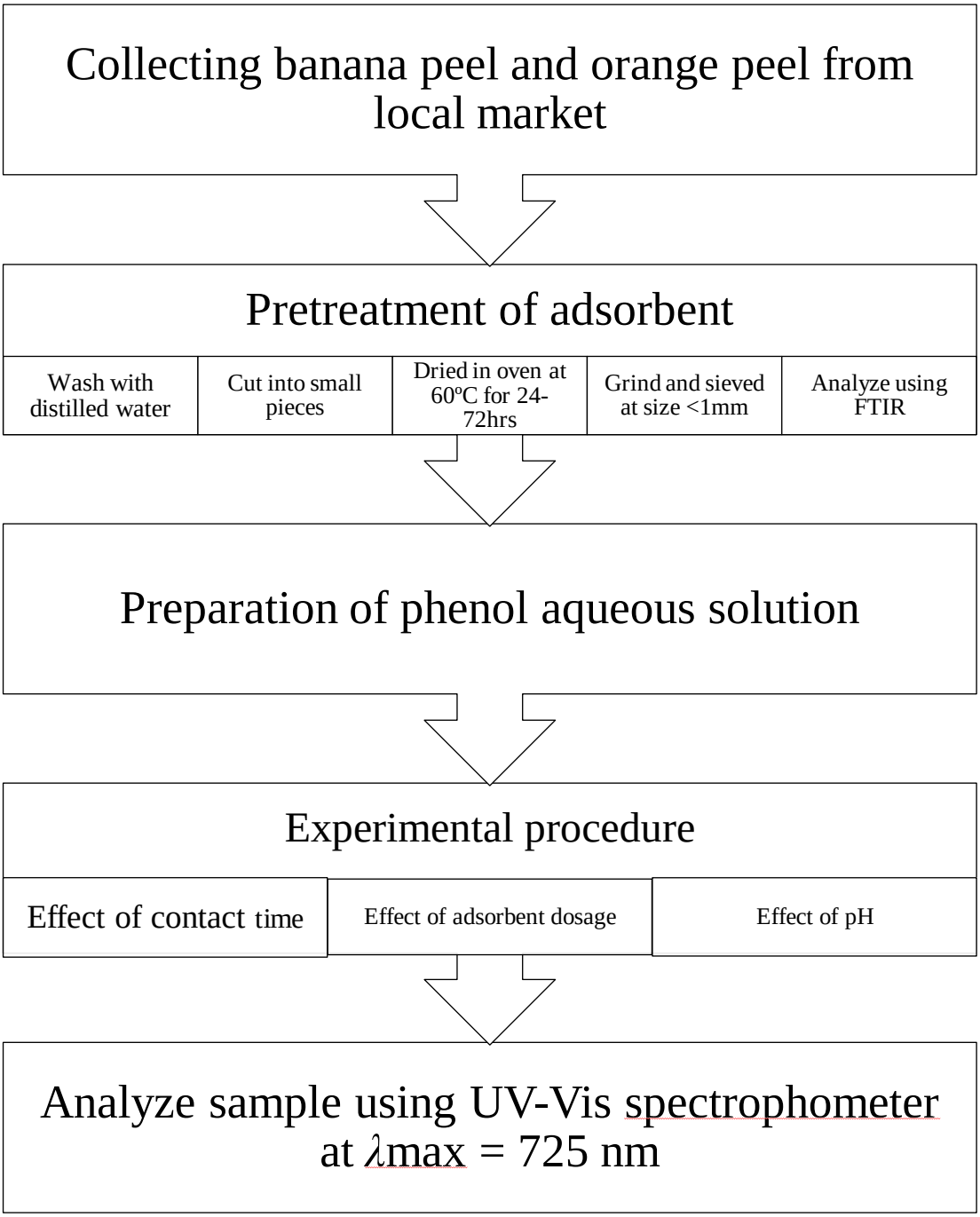

Figure 3.1: Schematic flowchart for adsorption process in removal of phenol

3.2 Equipment/Apparatus

During the research, equipment and apparatus are used in order to complete the research process. The equipment and apparatus used are as following: Volumetric flask 100ml, 500ml and 1000ml, Beaker 50ml and 100ml, Conical flask 250ml, Measuring cylinder 10ml and 25ml, Magnetic stirrer, Glass rod, Cone cylinder, Hot plate and stirrer, Whatman filter paper, Syringe 5ml, 10ml and 25ml, pH meter, Hitachi UV-Visible Spectrophotometer with cuvette, Orbital Shaker, Eppendorf refrigerated centrifuge, Memmert oven , Laboratory dry blender, Sieve tray, Fourier Transform Infra Red (FTIR)

3.3 Chemical/Reagents

There are several reagents used in order to complete the research process.
List of chemical/reagents used:

i. Phenol in crystal form from Sigma-Aldrich
ii. Sodium Carbonate powder from Sigma-Aldrich
iii. 0.1M Hydrochloric Acid
iv. 0.1M Sodium Hydroxide
v. Folin-Ciocalteu reagent
vi. Distilled water

3.4 Adsorbent preparation

Banana peel and orange peel is collected from local market of industrial area. The collected biomaterial was extensively washed under tap water to remove any particulate, sprayed with distilled water. This adsorbent is cut into small pieces, dried in convection oven at 60^{o}C, crushed using dry blender and sieved through a 1mm size before use it in adsorption experiments without any further treatment. Then, the characteristic of the adsorbent is analyzed by using Fourier Transform Infra Red to define the functional group in the adsorbent.

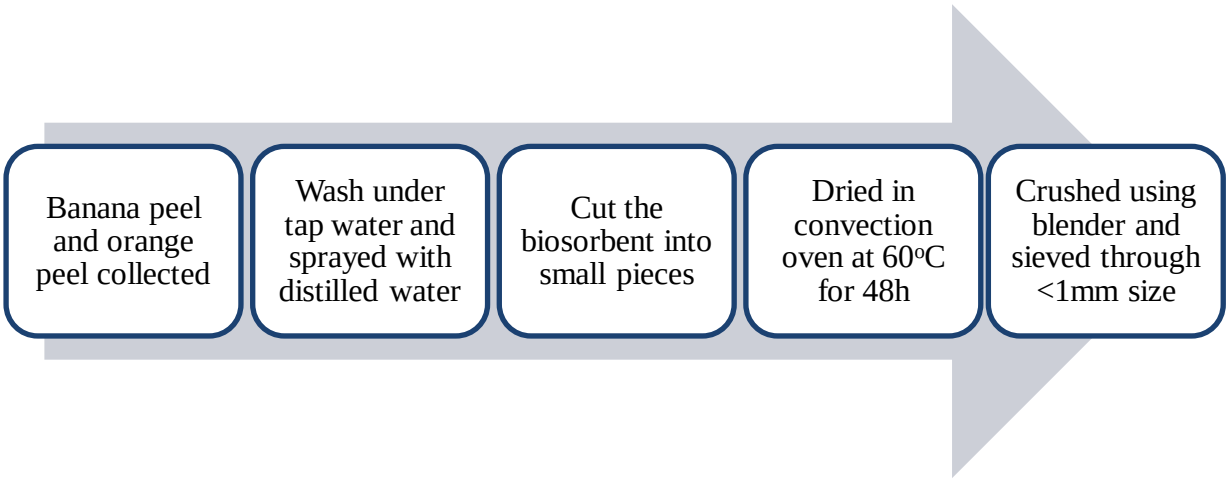

Figure 3.2: Flowchart for adsorbent preparation

Figure 3.3: Banana peel

Figure 3.4: Orange peel

Figure 3.5: Banana peel adsorbent

Figure 3.6: Orange peel adsorbent

3.5 Preparation of phenol aqueous solution

The solution is prepared in distilled water. A stock solution of phenol is prepared by dissolving 0.5g phenol in crystal form in 1000mL capacity volumetric flask. This is treated as stock solution of phenol (500mg/L)

3.6 Adsorption experiments

3.6.1 Effect of adsorption time

The effect of contact time is investigated for 10 to 720 minutes at pH 5.73 with adsorbent dosage amount is 0.5g (0.25%w/v) and initial concentration of 100mg/L in 200ml of solution. Flask of sample were seal using alumunium foil and shaken by using orbital shaker at 200 rpm. After centrifuge and filter the sample, the supernatant were analyzed by using UV-Vis spectrophotometer. The similar pattern experiments were carried out 2 times in order to validate the result.

3.6.2 Effect of adsorbent dosage

For studying the effect of absorbent dose, 0.2g to 5.0g of banana and orange peel dosage was used with the initial concentration is 100 mg/L. All the other parameter was constantly, at pH 5.73 and contact time 240 minutes. Flask of sample were seal using alumunium foil and shaken by using orbital shaker at 200 rpm. After centrifuge and filter the sample, the supernatant were analyzed by using UV-Vis spectrophotometer. The similar pattern experiments were carried out 2 times in order to validate the result.

3.6.3 Effect of initial pH

The initial pH of solution was adjusted from pH 3 to 13 by using 0.1 M HCl and 0.1 M NaOH at same value of adsorbent dosage and initial. Flask of sample were seal using alumunium foil and shaken by using orbital shaker at 200 rpm. After centrifuge and filter the sample, the supernatant were analyzed by using UV-Vis spectrophotometer. The similar pattern experiments were carried out 2 times in order to validate the result. The contact time is fixed at 240 minutes.

3.7 Analysis procedure

The analysis was done by using the UV- Vis spectrometer (Model U-1800, Hitachi). Before doing the analysis, 10ml of supernatant solution after centrifuge and filtrate is added with 10ml of distilled water, 3ml of 200mg/L sodium carbonate solution, and 1ml of Folin-Ciocalteu reagent and leave for 1 hour. This method is based on previous study on investigation of phenol which known as Box method (J. D. Box, 1983)

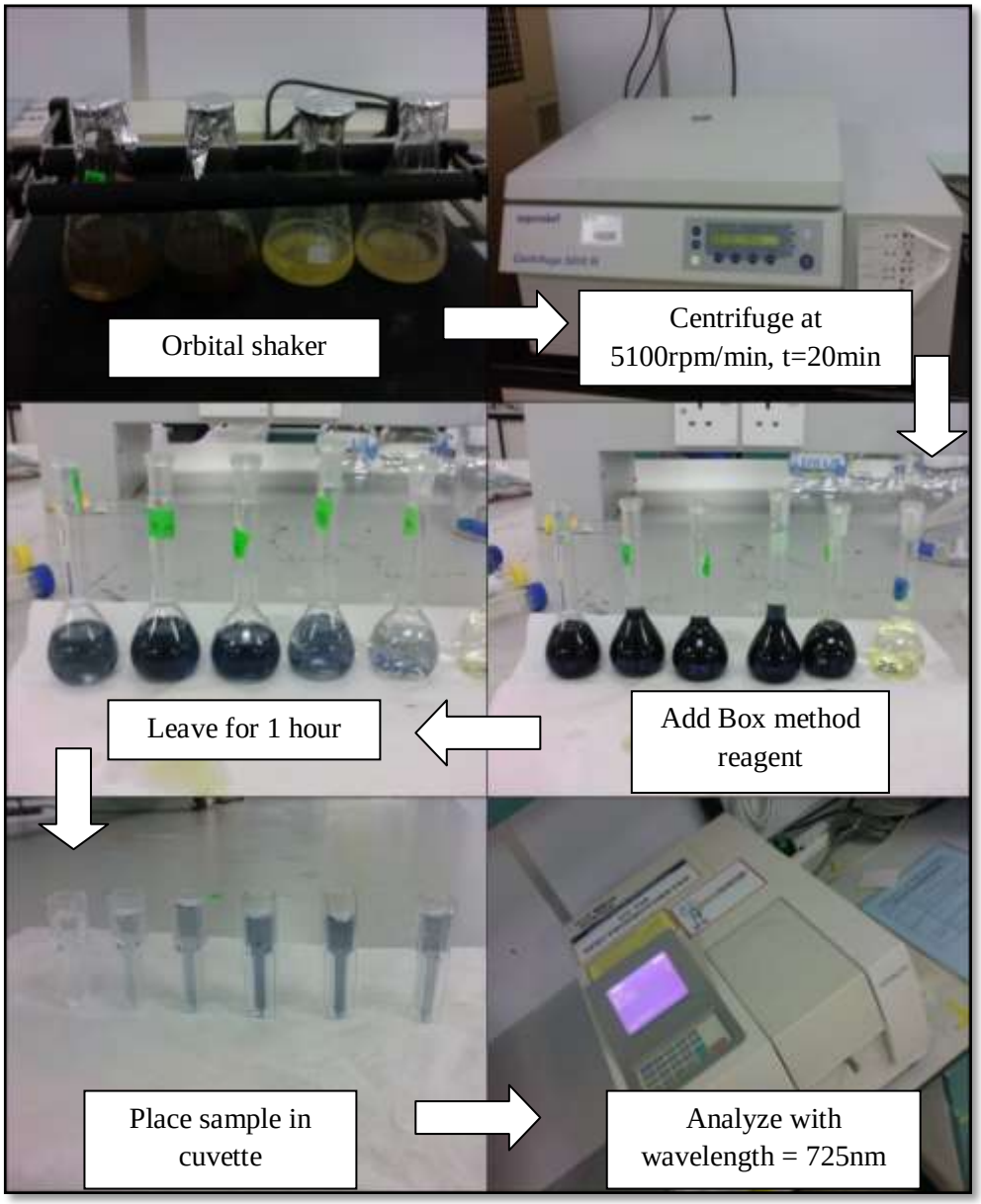

Figure 3.7: General procedure for adsorption of phenol process

CHAPTER 4

RESULT AND DISCUSSION

4.1 Effect of adsorption time

The percentage of phenol removal as a function of time is shown in Figure 4.1, with the condition of initial concentration (100mg/L), initial dosage of adsorbent (0.5g), speed shaker (200 rpm) and pH at 5.73. The time contact varying in the range 10 min- 720 min. Based on the result obtain, the percentage of phenol removal consider constantly at 240-360 minutes. It can be explain that the uptake of phenol by adsorbent increase when the time increase until it reach equilibrium state. At time 240 minutes of time contact the phenol uptake is 94% and the percentage continue with small change in percentage. The uptake of phenol per mass of adsorbent for banana peel is 37.67 mg/g for this concentration.

From the Figure 4.1, it shows that phenol uptake rapidly increase at time 20 minutes to 40 minutes. This is due to the adsorption activity that take place in the inner surface of the adsorbent. At time 60 minutes to 240 minutes, the phenol uptake still increase but the adsorption activity is tak

place at the outer surface of adsorbent due to saturated condition in inner surface. This process is called second layer adsorption.

The adsorption activities continue slower rate until it achieved the saturated condition in both surface. In this condition, the adsorbent capacity is at maximum level and the adsorption process reached a dynamic equilibrium which means the amount of phenol being adsorbed onto adsorbent was equal to the amount of phenol being desorbed from adsorbent and the adsorption amount remained approximated constant.

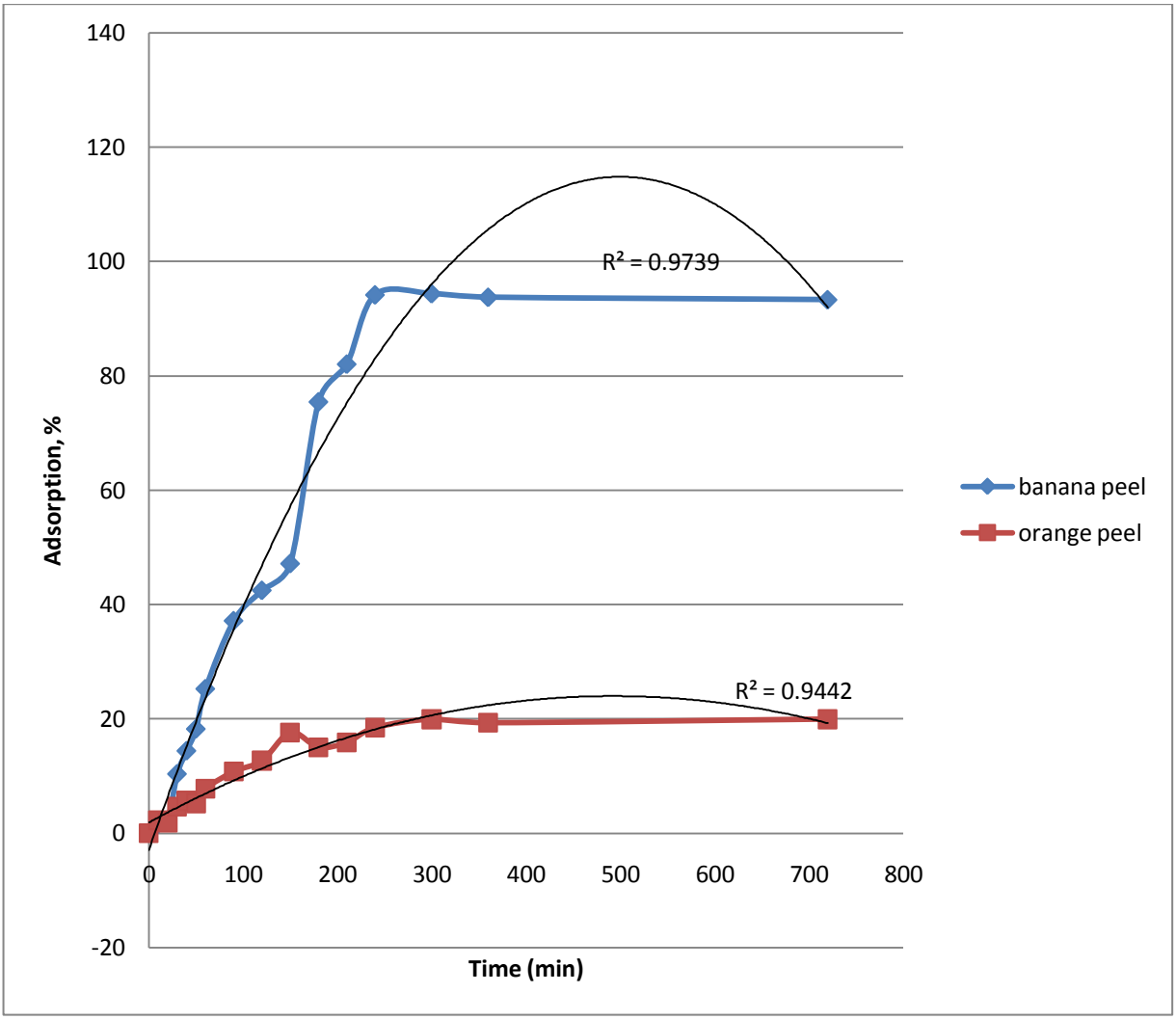

Figure 4.1: Graph of percentage phenol adsorb by adsorbent on effect of adsorption time.

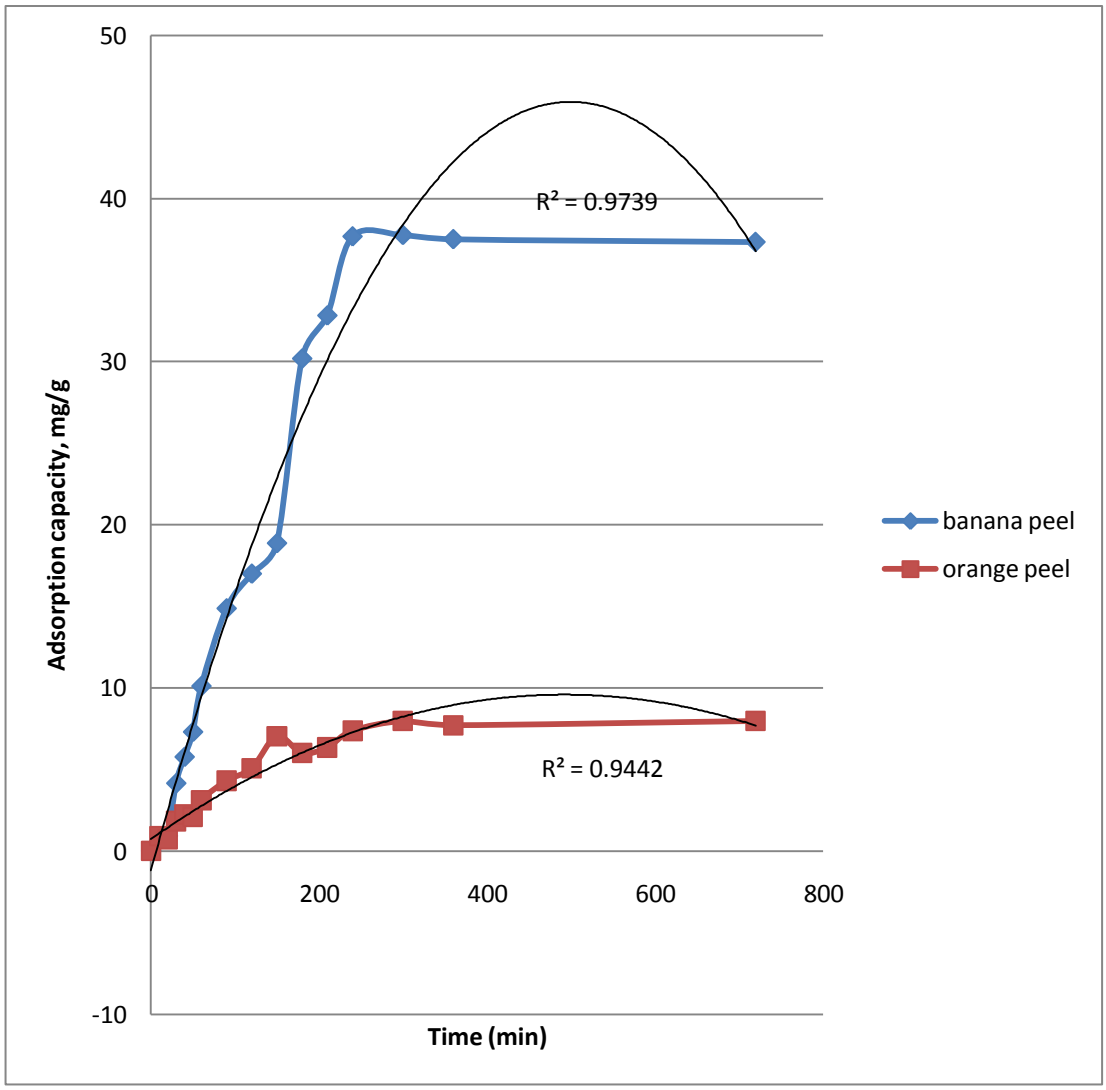

Figure 4.2: Graph of adsorption capacity per unit mass of adsorbent on effect of adsorption time

4.2 Effect of adsorbent dosage

The effect of adsorbent dosage on the absorptive removal of phenol by banana peel and orange peel is shown in Figure 4.3. In order to investigate the effect of initial dosage of adsorbent by using banana and orange peel, a series of adsorption experiments were conducted with different amount of adsorbent dosage range from 0.2g to 5.0g while keeping the other parameters constant (C_0=100mg/L, pH= 5.73, time=240 min). It was observe that the amount of phenol adsorbed varied with varying amount of adsorbent dosage.

From Figure 4.3, it shows that the increment of adsorbent amount will increase the percentage of adsorption process due to the amount of vacant surfaces provides by the adsorbent. Phenol removal is increased by amount of adsorbent for banana peel adsorbent. From graph 4.3, the percentage of phenol removal is increase with adsorbent dosage from 10% to 88.57% with adsorbent dosage varied from 0.2g to 5.0g. But, for orange peel adsorbent, the amount of phenol removal is higher when in low amount of adsorbent. At dosage of 0.2g, the percentage of adsorption is 24.83% and it will decreased by increment of adsorbent dosage. This is maybe due to the charge produce from the orange peel which is slightly acidic that produce more positive charge ion and it will increase the concentration of phenol.

Based on Figure 4.4, the graph shows that the adsorption capacity per unit mass of adsorbent for both type of biosorbent is decrease by increasing the amount of adsorbent. The highest adsorption capacity was found at the low amount of adsorbent which is at dosage 0.4g and the adsorption capacity is 11.27mg/g. Many factors can contribute to this effect. The most important factor is that adsorption sites remain unsaturated during the adsorption reaction. This result also may be due to the decrease in total adsorption surface area available to phenol resulting from overlapping or aggregation of

adsorption sites. This decrease in adsorption capacity with the increase in adsorbent dosage is mainly attributed to the non-saturation of the adsorption sites during the adsorption process.

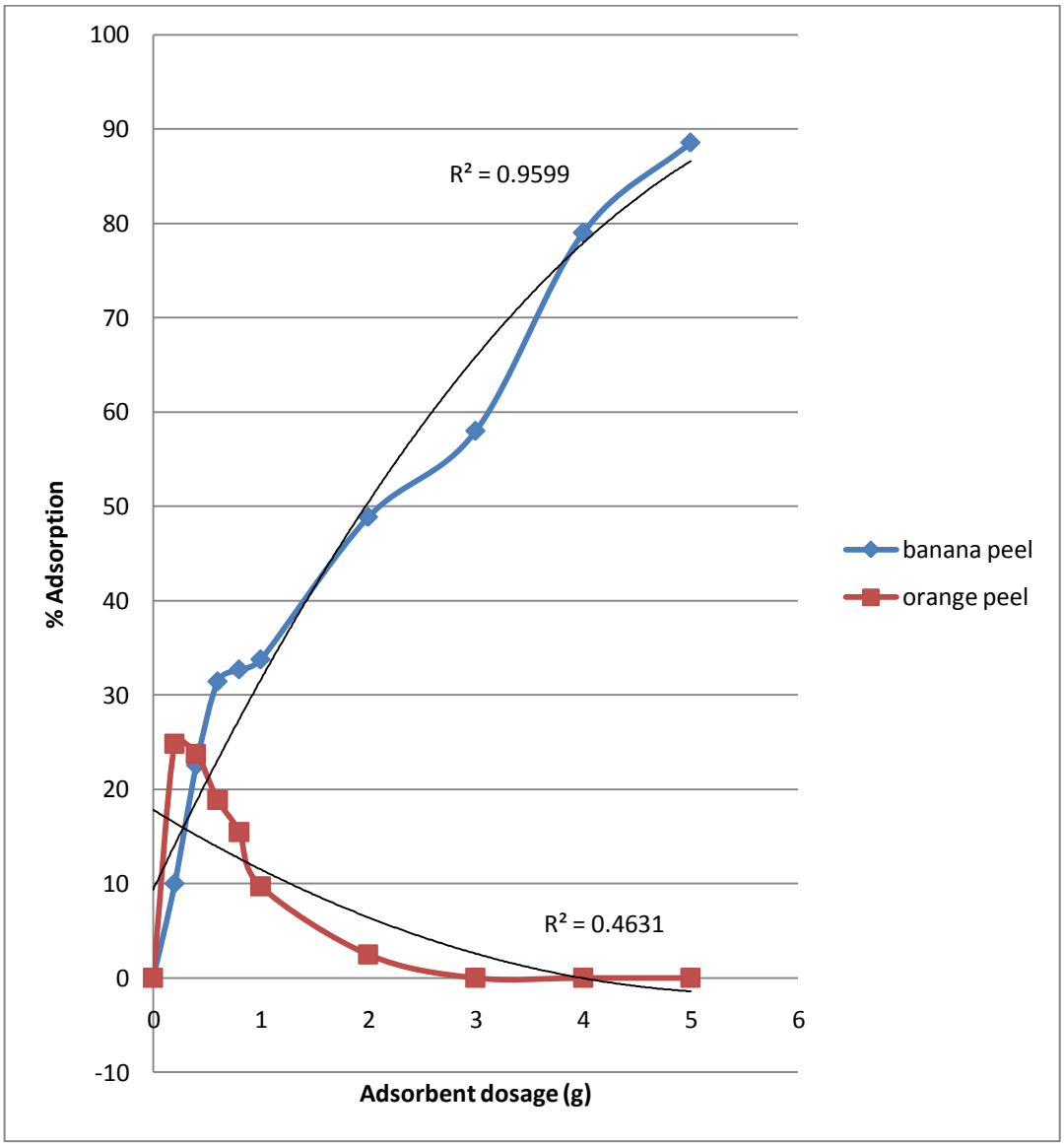

Figure 4.3: Graph of percentage phenol adsorb by adsorbent on effect of adsorbent dosage

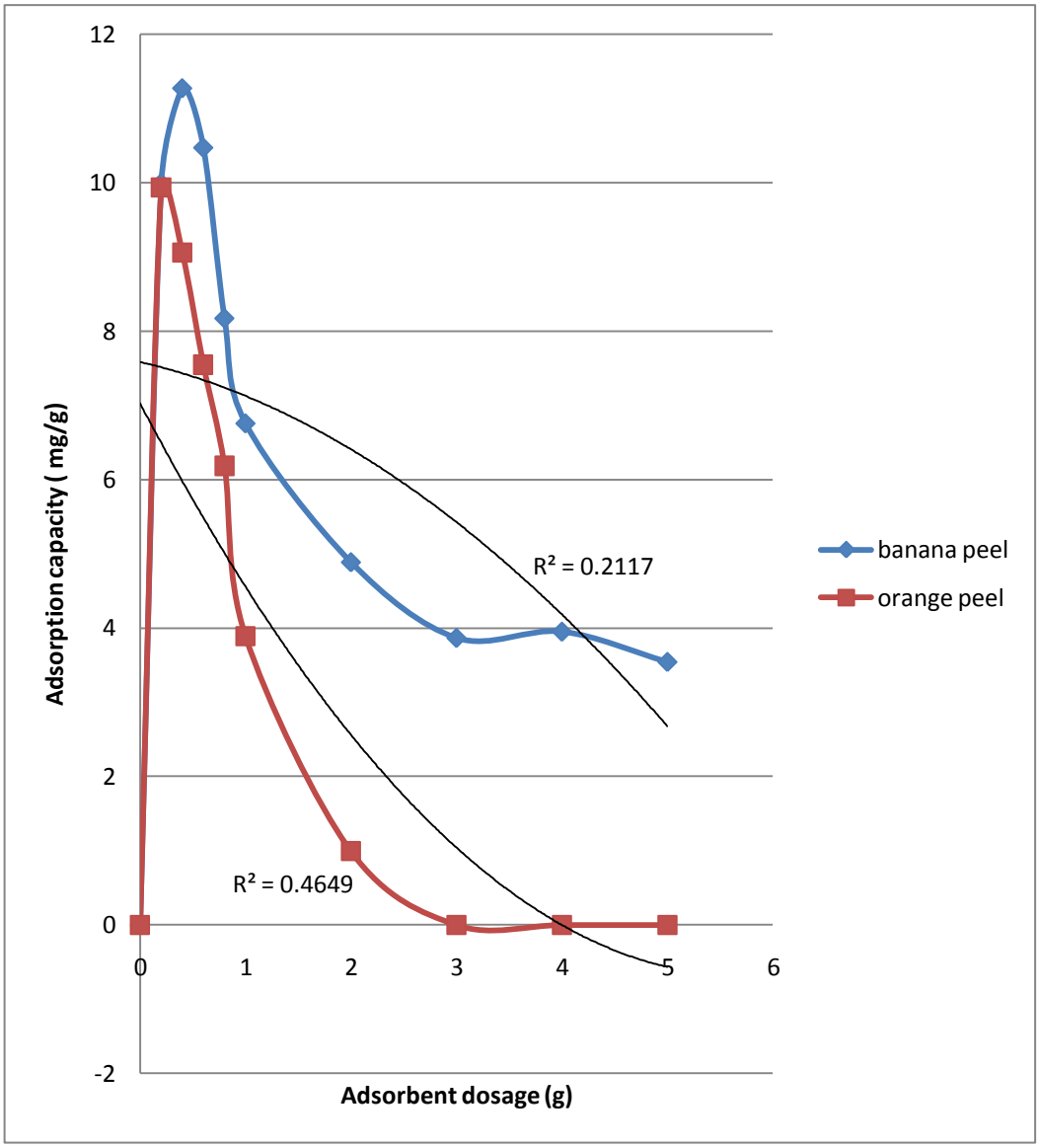

Figure 4.4: Graph of adsorption capacity per unit mass of adsorbent on effect of adsorbent dosage

4.3 Effect of pH

One of the important parameter that can influence the adsorption capacity is the pH of adsorption medium which is phenol aqueous solution. (N.Goyal *et.al.,* 2003). The final pH of the adsorption medium affects the adsorption mechanism on the adsorbent surface and influences the nature of physicochemical interactions of the species in solution and the adsorptive sites of adsorbents. (Z. Aksu *et.al.*, 2002)

The determine the adsorption process on effect of pH of adsorption medium by using banana peel and orange peel, a series of adsorption experiments were conducted with varied value of pH from 3 to 11 while the other parameters is remain constant (C_0=100mg/L, adsorbent dosage=0.5g, time=240 min).

From Figure 4.5, the graph shows that phenol concentration is decreased with increment of pH value by using both type of adsorbent. When using banana peel as adsorbent, the adsorption efficiency increased from 9.72% to 57.16% when pH of solution varied from 3 to 11. As it is well established, pH affects the degree of ionization of the phenol compound. Banana peel material is composed of various functional group such as amino and carboxyl which also could be affected by the pH. At lower pH value, phenol is present as the acidic compound. At higher pH value the concentration of the negative charge ion increase. The adsorption is increase from pH 7 to pH 11. For orange peel adsorbent the phenol concentration is increase at lower pH solution due to the H^+ ion released from the solution.

Based on Figure 4.6, the graph shows that the adsorption capacity per unit mass of adsorbent is increase with the increment of pH solution. This is due to the amount of OH^- charge increase when pH value is increase. So

percentage of phenol removal is increase due to the amount of OH^- ion attract with H^+ ion in phenol solution which considered as weak acid.

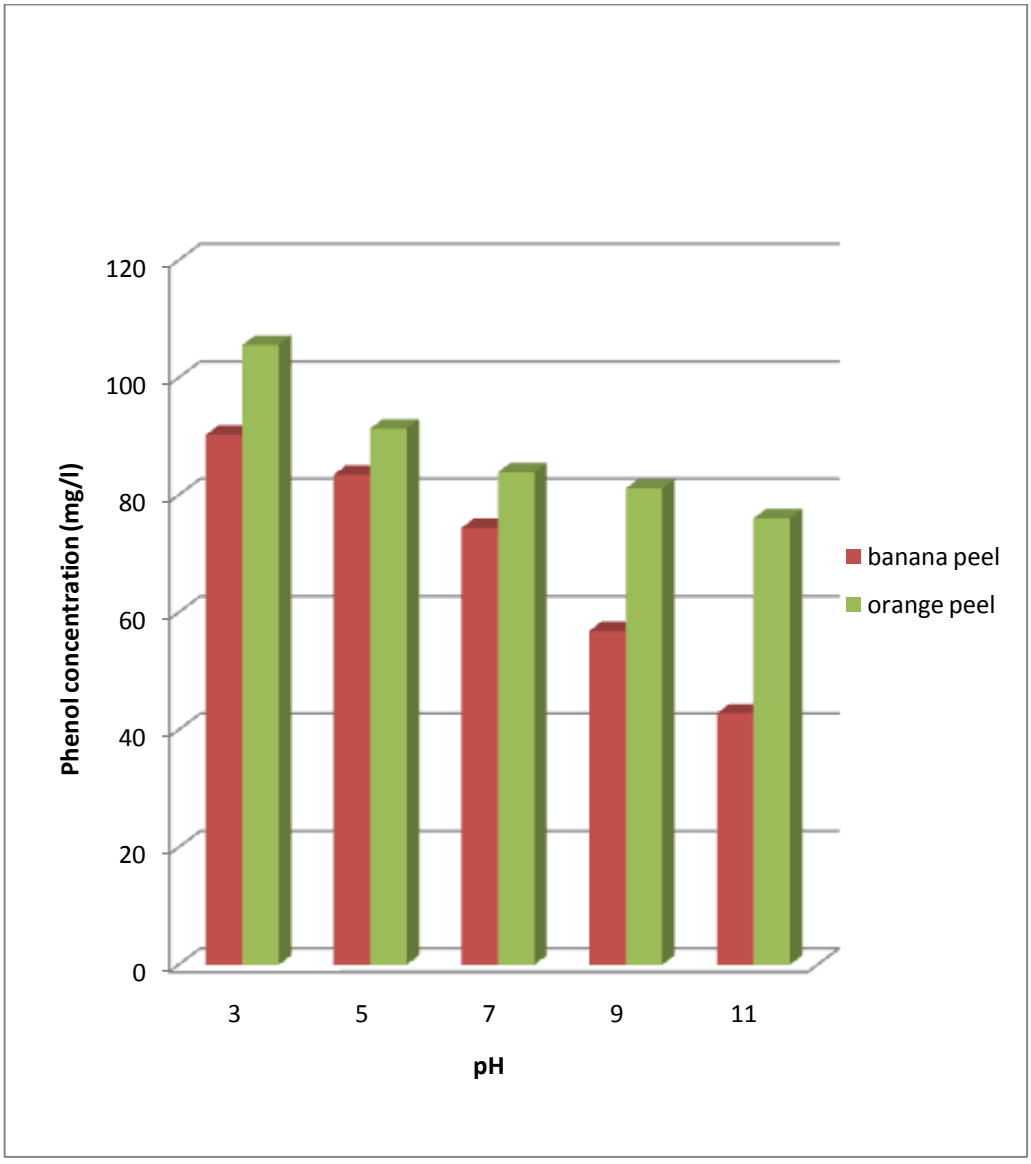

Figure 4.5: Graph of phenol concentration on effect of pH

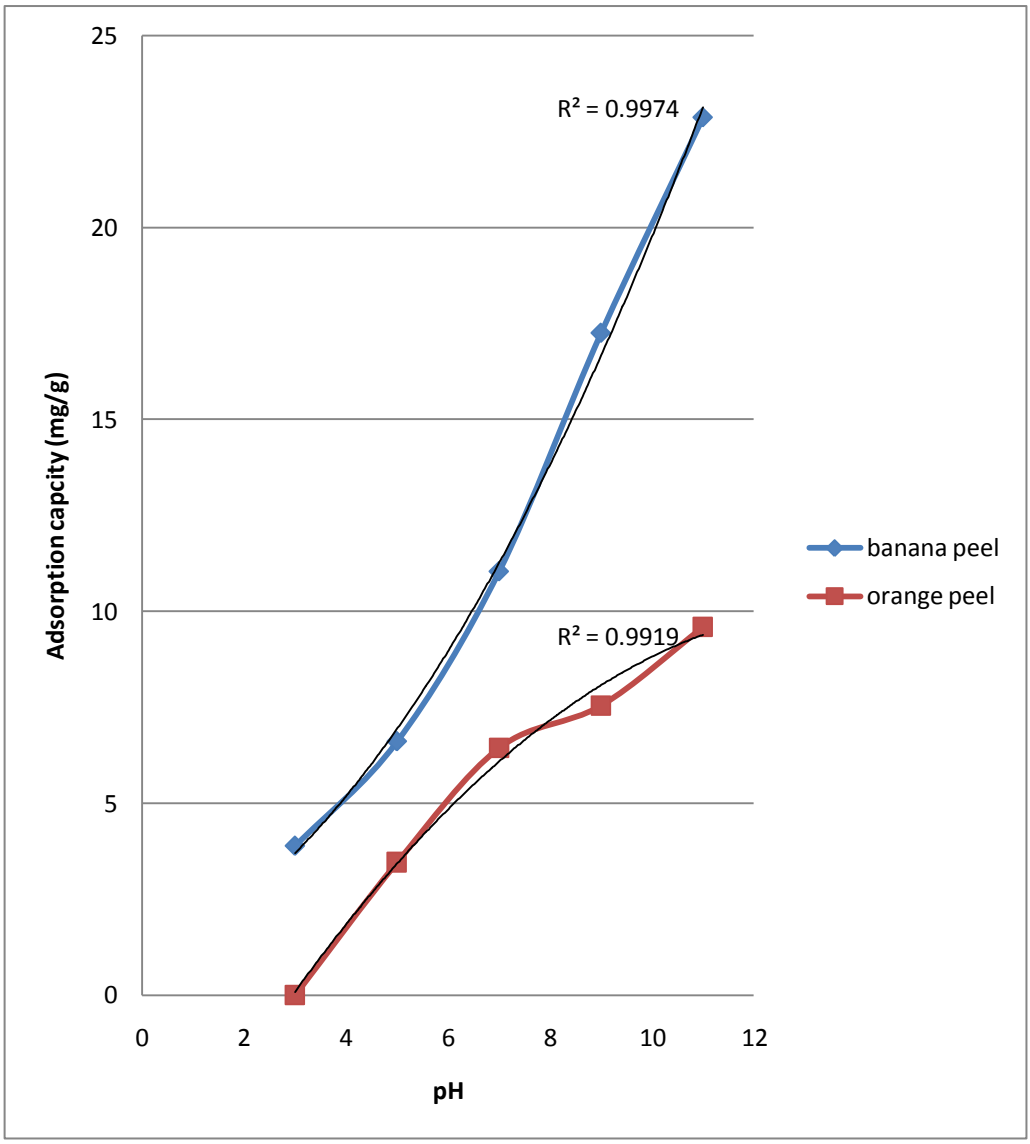

Figure 4.6: Graph of adsorption capacity per unit mass of adsorbent on effect of pH

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The objective of this study is to see the efficiency of banana peel and orange peel as a low cost adsorbent in removal of phenol. Result and data obtained in this study proven that adsorption of phenol by using banana peel and orange peel is successful. For banana peel, the percentage of adsorption is increased with all parameters which are adsorption time, adsorbent dosage and pH of adsorption medium. For adsorption time, the optimum time that gives the highest phenol removal is 240 minutes with percentage of removal is 94.2% and after this time, the percentage of removal is approximately constant. For adsorbent dosage scope, the percentage of phenol removal is increase with increment of dosage, but the adsorption capacity is vice versa. So, the optimum adsorbent dosage for banana peel is 0.4g to 0.6g which gives the highest value of adsorption capacity (11.273mg/g). As for pH of adsorption medium which is phenol, the optimum value is around pH 9 to 11 which gives the percentage of removal increase to 57.2%. For orange peel as adsorbent, the percentage of removal is too small compared to banana peel. The highest percentage of phenol removal by using orange peel is 24% with condition of 240 minutes adsorption time, 0.5g adsorbent (2.5% w/v) and at pH 11.

From the result obtained, we can conclude that banana peel and orange peel can be one type of low cost adsorbent is removal of phenol from aqueous solution but banana peel is better compared to orange peel. As the results shows, there was some point of decreasing while it should increase as the expected due to some errors that might be had been occurs during the experiment such as contamination from the equipment used. There were also some errors during the measuring of reading and preparing the sample.

5.2 Recommendation

As recommendation for future study, we should consider this experiment of the removal continue by running it in an adsorption column. This can consider the adsorption process same as the industrial treatment. We also should continue this experiment by using the industrial waste water such as olive oil production.

For orange peel as an adsorbent in this removal of phenol, further study should be done to analyze the characteristic of orange peel that will increase the percentage of phenol removal in water. A few treatments should be done before orange peel can be used as one type of a low cost adsorbent in removal of phenol.

Moreover, we also can add the parameter to be studied to obtain the best condition that will gives the highest percentage of phenol removal such as the effect on different adsorbent particle size. This is due to the difference of particle sizes contributes to the inconsistency of the binding sites and pore distribution. It is best to consider the effects of the variation of adsorbent particle sizes hence the sorption activity can be investigated at its optimum surface texture of the sorbent.

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APPENDIX A

EXPERIMENTAL RESULT

Table A.1: Effect of adsorption time for banana peel

Time (min)	Abs x DF	Ce (mg/L)	% ads	q_e (mg/g)
0	0	100	0	0
10	9.44	98.37	1.63	0.652
20	9.38	97.73	2.27	0.908
30	8.62	89.64	10.36	4.144
40	8.24	85.6	14.4	5.76
50	7.88	81.77	18.23	7.292
60	7.22	74.75	25.25	10.1
90	6.1	62.84	37.16	14.864
120	5.6	57.52	42.48	16.992
150	5.16	52.84	47.16	18.864
180	2.5	24.54	75.46	30.184
210	1.88	17.94	82.06	32.824
240	0.74	5.816	94.184	37.6736
300	0.72	5.603	94.397	37.7588
360	0.78	6.24	93.76	37.504
720	0.82	6.67	93.33	37.332

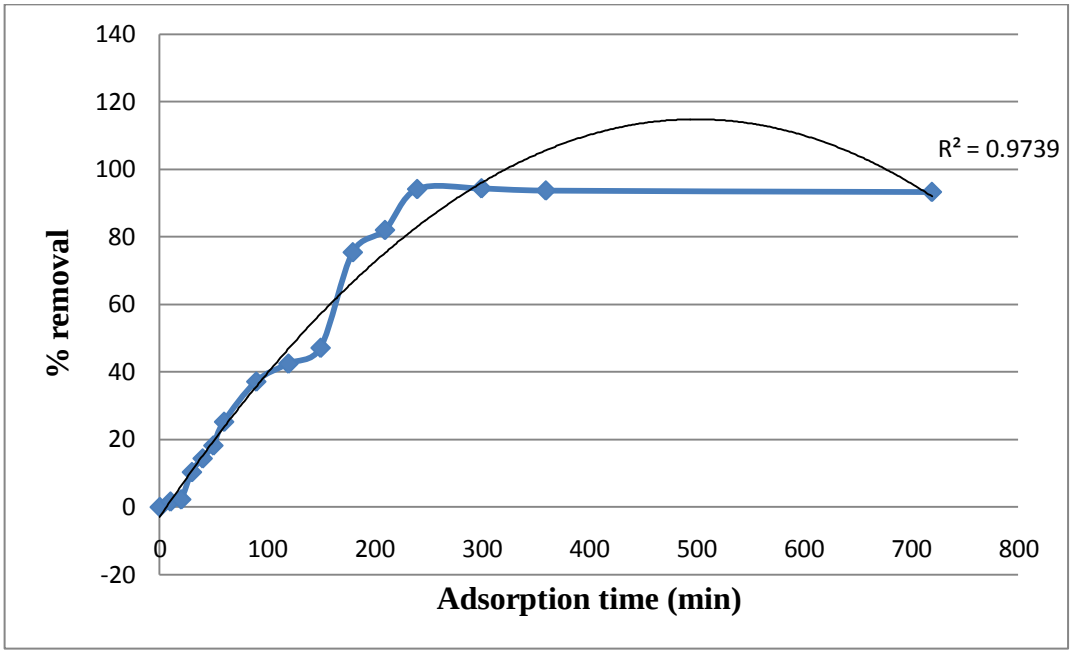

Figure A.1: Graph of percentage phenol removal versus adsorption time by using banana peel as adsorbent

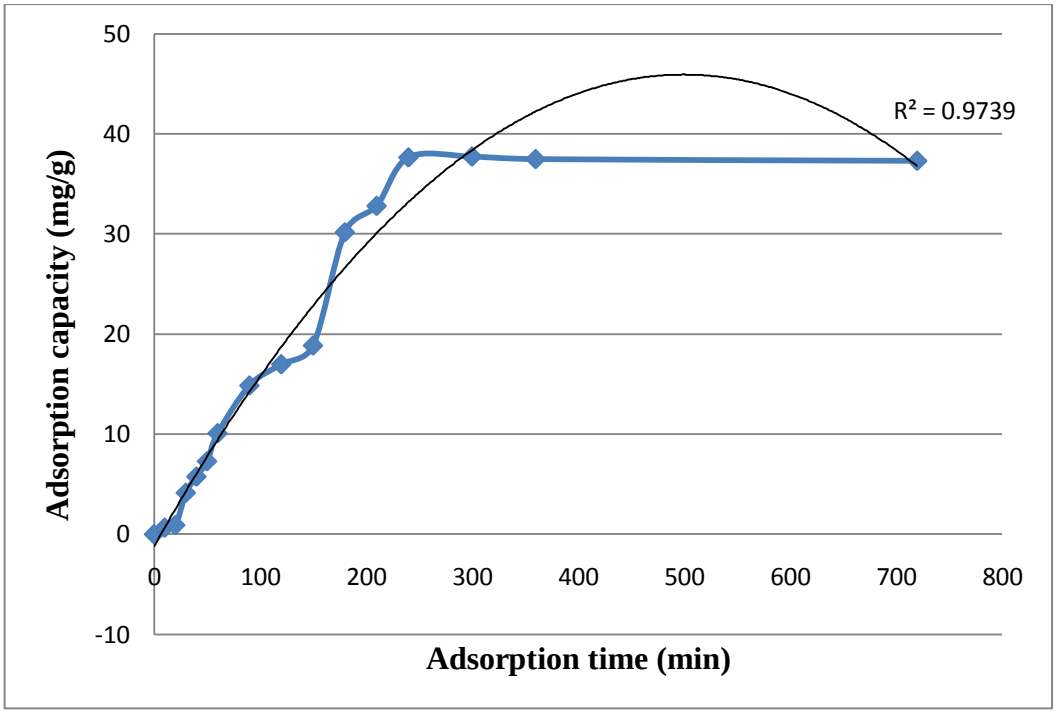

Figure A.2: Graph of adsorption capacity per unit mass of adsorbent versus adsorption time by using banana peel as adsorbent

Table A.2: Effect of adsorption time for orange peel

Time (min)	Abs x DF	Ce (mg/L)	% ads	qe (mg/g)
0	0	100	0	0
10	9.38	97.73	2.27	0.908
20	9.42	98.156	1.844	0.7376
30	9.16	95.39	4.61	1.844
40	9.06	94.33	5.67	2.268
50	9.10	94.75	5.25	2.1
60	8.86	92.189	7.811	3.1244
90	8.58	89.22	10.78	4.312
120	8.4	87.305	12.695	5.078
150	7.94	82.412	17.588	7.0352
180	8.18	84.965	15.035	6.014
210	8.1	84.114	15.886	6.3544
240	7.86	81.56	18.44	7.376
300	7.72	80.07	19.93	7.972
360	7.78	80.71	19.29	7.716
720	7.72	80.07	19.93	7.972

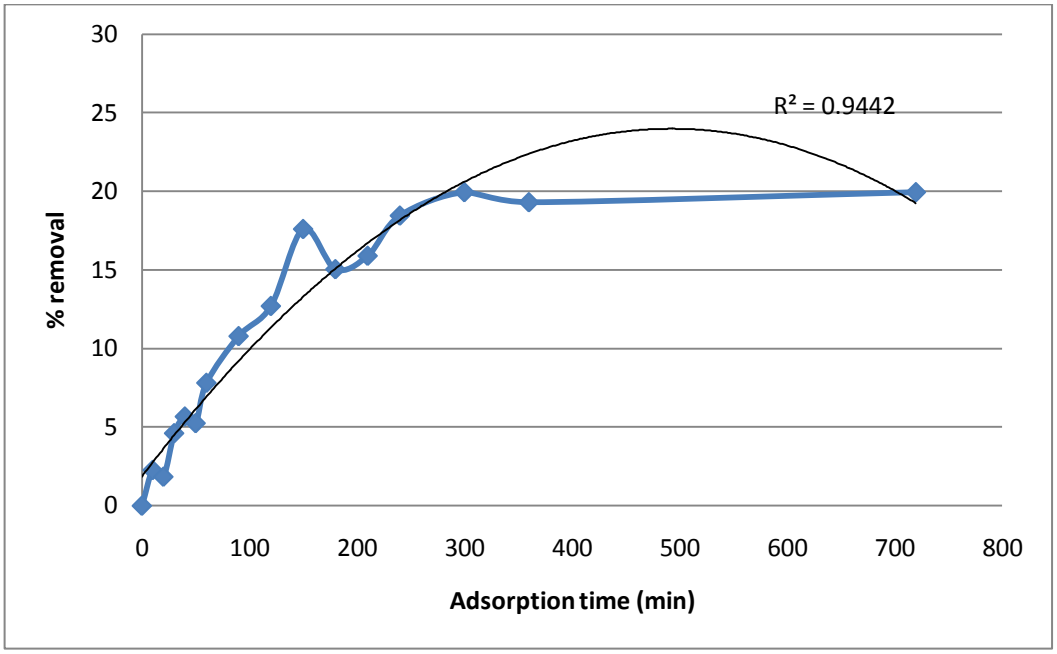

Figure A.3: Graph of percentage phenol removal versus adsorption time by using orange peel as adsorbent

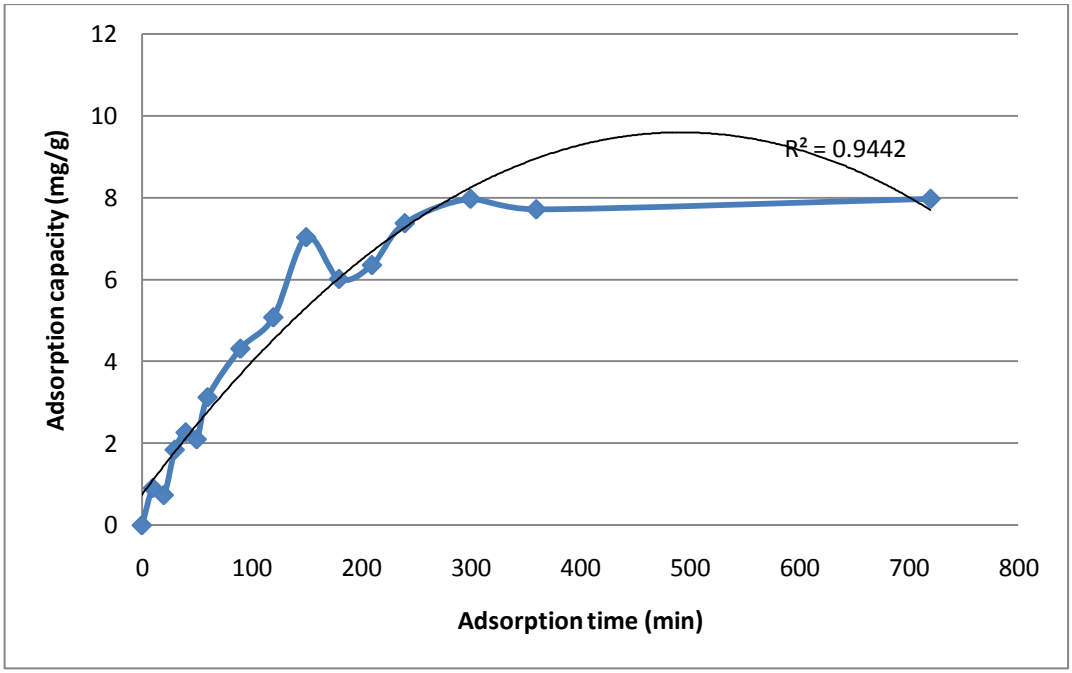

Figure A.4: Graph of adsorption capacity per unit mass of adsorbent versus adsorption time by using orange peel as adsorbent

Table A.3: Effect of adsorbent dosage for banana peel

Adsorbent dosage (g)	Abs x DF	Ce (mg/L)	%ads	q_e (mg/g)
0	0	100	0	0
0.2	8.65	90.007	9.993	9.993
0.4	7.47	77.454	22.546	11.273
0.6	6.64	68.582	31.418	10.472
0.8	6.52	67.305	32.695	8.173
1	6.42	66.2415	33.7585	6.757
2	5.00	51.135	48.865	4.8865
3	4.142	42.0074	57.9925	3.8662
4	2.166	20.986	79.014	3.9507
5	1.268	11.433	88.567	3.5427

Table A.4: Effect of adsorbent dosage for orange peel

Adsorbent dosage (g)	Abs x DF	Ce (mg/L)	%ads	q_e (mg/g)
0	0	100	0	0
0.2	7.26	75.17	24.83	9.932
0.4	7.36	76.24	23.76	9.054
0.6	7.82	81.135	18.865	7.546
0.8	8.14	84.539	15.4606	6.18424
1	8.68	90.284	9.716	3.8864
2	9.36	97.518	2.482	0.9928
3	9.78	101.986	0	0
4	10.42	108.795	0	0
5	12.62	132.199	0	0

Table A.5: Effect of pH for banana peel

pH	Abs x DF	Ce (mg/L)	%ads	q_e (mg/g)
3	8.68	90.284	9.716	3.8864
5	8.04	83.475	16.525	6.61
7	7.00	74.4117	27.5883	11.03532
9	5.54	56.8798	43.1202	17.24808
11	4.22	42.837	57.163	22.865

Table A.6: Effect of pH for orange peel

pH	Abs x DF	Ce (mg/L)	%ads	q_e (mg/g)
3	10.12	105.603	0	0
5	8.78	91.348	8.652	3.4608
7	8.08	83.901	16.099	6.4396
9	7.82	81.135	18.865	7.546
11	7.34	76.029	23.971	9.5884

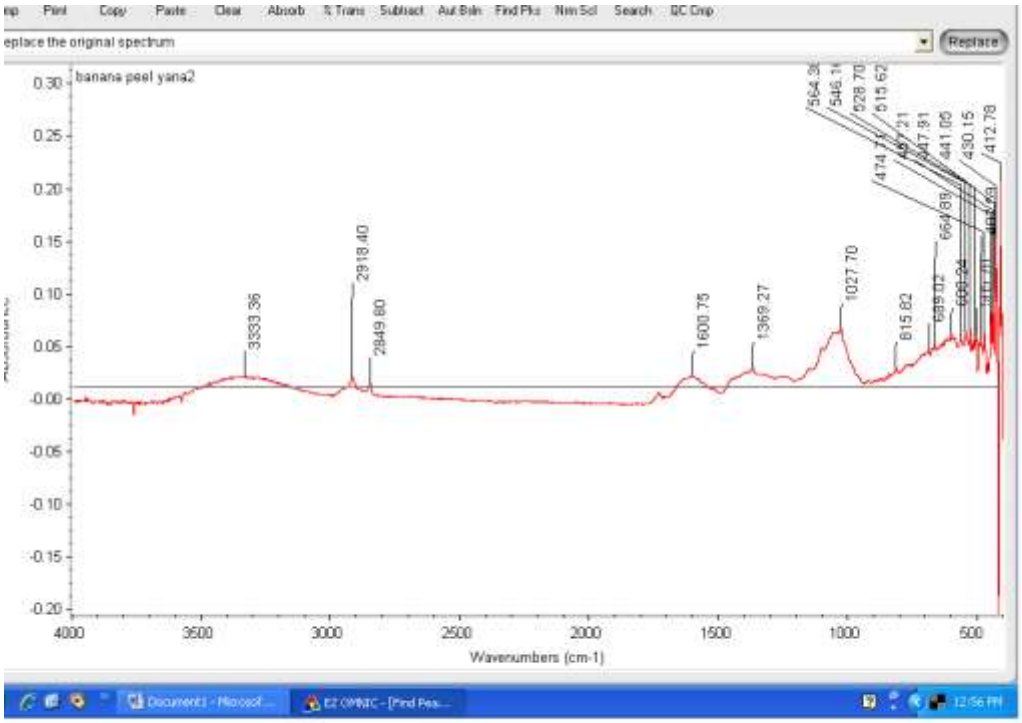

Figure A.5: FTIR analysis for functional group in banana peel

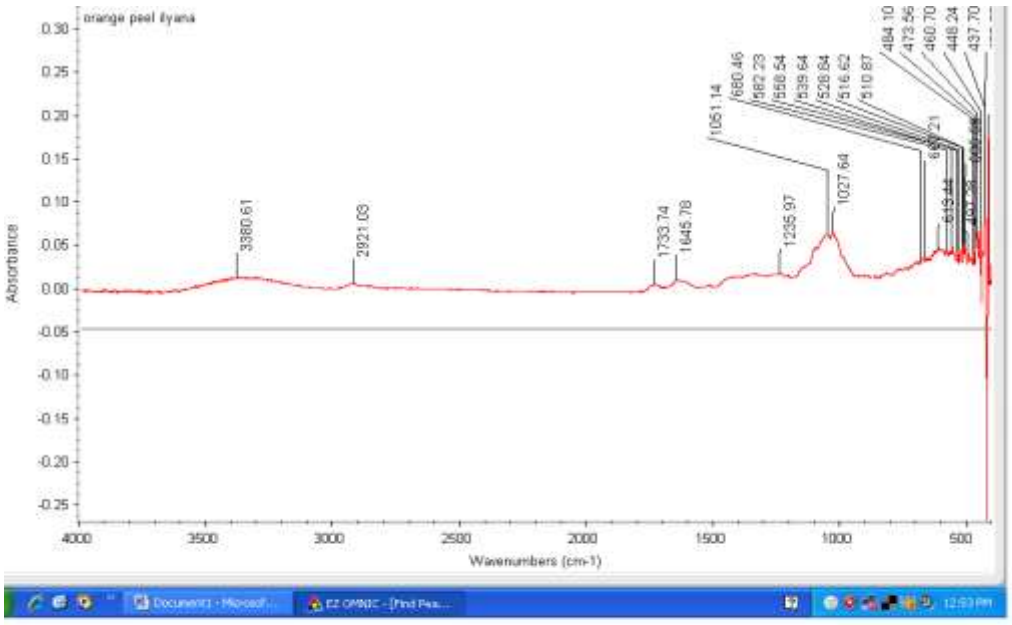

Figure A.6: FTIR analysis for functional group in orange peel

APPENDIX B

CALCULATION

1. **Calculation for adsorbent amount.**

0.1% w/v = 0.1/100 (200ml)
= 0.2g

0.2% w/v = 0.2/100 (200ml)
= 0.4g

0.3% w/v = 0.3/100 (200ml)
= 0.6g

0.4% w/v = 0.4/100 (200ml)
= 0.8g

0.5% w/v = 0.5/100 (200ml)
= 1.0g

1% w/v = 1/100 (200ml)
= 2g

1.5% w/v = 1.5/100 (200ml)

= 3g

2% w/v = 2/100 (200ml)

= 4g

2.5% w/v = 2.5/100 (200ml)

= 5g

2. Calculation for concentration of standard curve solution.

$M_1V_1=M_2V_2$

500mg/L (V_1) = 20mg/L (0.05L)

V_1 = 2ml phenol stock solution

$M_1V_1=M_2V_2$

500mg/L (V_2) = 40mg/L (0.05L)

V_2 = 4ml phenol stock solution

$M_1V_1=M_2V_2$

500mg/L (V_3) = 60mg/L (0.05L)

V_3 = 6ml phenol stock solution

$M_1V_1=M_2V_2$

500mg/L (V_4) = 80mg/L (0.05L)

V_4 = 8ml phenol stock solution

$M_1V_1=M_2V_2$

500mg/L (V_5) = 100mg/L (0.05L)

V_5 = 10ml phenol stock solution

3. Calculation for preparation of 0.1M HCL

Molecular weight = 36.45 g/mol

Purity = 37%

Density = 1.18 g/cm^3

$$\text{Molarity} = \frac{\text{Density} \times \text{Purity} \times 1000\text{ml}}{\text{Molecular weight}}$$

$$= \frac{1.18\ g/cm^3 \times 0.37 \times 1000ml}{36.45\ g/mol}$$

= 11.98 mol/L

$M_1V_1=M_2V_2$

11.98 mol/L (V_1) = 0.1mol/L (0.25L)

V_1 = 2.087ml phenol stock solution

4. Calculation for preparation of 0.1M NaOH

Molarity =0.1mol/L

Mole = Molarity × Volume

= 0.1 mol/L × 0.25L

= 0.025 mol

Mass = Mole × Molecular weight

= 0.025 mol × 40g/mol

= 1g of NaOH

5. Calculation for preparation of Na_2CO_3

C_0 = 200g/L

Molecular weight = 106 g/mol

$$\text{Molarity} = \frac{200\ g/L}{106g/mol}$$

= 1.8868 mol/L

Mole = Molarity × Volume

= 1.8868 mol/L × 0.5L

= 0.9434mol

Mass = Mole × Molecular weight

= 0.9434mol × 106g/mol

= 100g of Na_2CO_3

6. Calculation for phenol stock solution

C_0 = 500mg/L

Molecular weight = 94.11 g/mol

$$\text{Molarity} = \frac{500 \text{ mg/L}}{94.11 \text{g/mol}}$$

$= 5.313\times10^{-3}$mol/L

Mole = Molarity × Volume

$= 5.313\times10^{-3}$ mol/L × 1L

$= 5.313\times10^{-3}$mol

Mass = Mole × Molecular weight

$= 5.313\times10^{-3}$ mol × 94.11g/mol

= 0.5g of C_6H_5OH

APPENDIX C

STANDARD CALIBRATION CURVE FOR PHENOL

Table C.1: Standard calibration curve

Phenol concentration (mg/L)	**Abs 1**	**Abs 2**	**Abs 3**	**Abs average**	**Abs x DF=20**
20	0.114	0.114	0.114	0.114	2.28
40	0.197	0.196	0.197	0.197	3.94
60	0.299	0.299	0.299	0.299	5.98
80	0.396	0.394	0.395	0.396	7.92
100	0.474	0.474	0.474	0.474	9.48

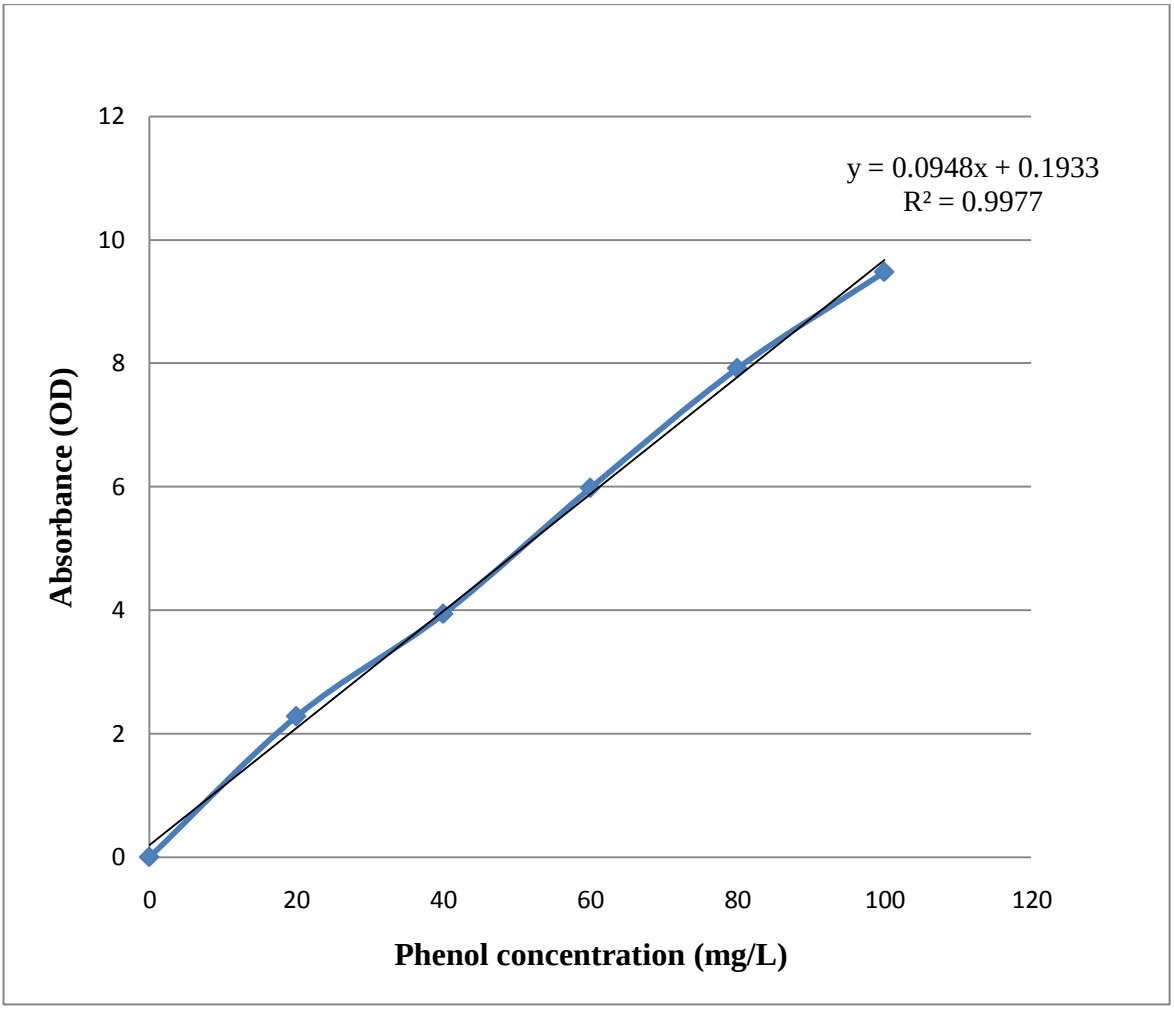

Figure C.1: Graph of standard calibration curve for phenol

APPENDIX D

MATERIAL SAFETY DATA SHEET

Safety Data for Phenol

General

Synonyms: benzenol, carbolic acid, hydroxybenzene, monohydroxybenzene, monophenol, oxybenzene, phenic acid, phenylic acid, phenyl alcohol, phenyl hydrate, phenyl hydroxide and phenylic alcohol.

Molecular formula: C_6H_5OH

CAS No: 108-95-2

EC No: 203-632-7

Annex I Index No: 604-001-00-2

Physical Properties

Appearance: colorless crystals with a characteristic odor

Melting point: 40 - 42°C

Boiling point: 182°C

Specific gravity: 1.07

Vapor pressure: 0.35 mm Hg at 20°C

Flash point: 79°C

Explosion limits: 1.5 % - 8.6 %

Auto ignition temperature: 715°C

Stability

Stable. Substances to be avoided include strong oxidizing agents, strong bases, strong acids, alkalies, calcium hypochlorite. Flammable. May discolored in light.

Risk Phrases

R24 Toxic in contact with skin

R25 Toxic if swallowed

R34 Causes burns

R36 Irritating to eyes

R37 Irritating to respiratory system

R38 Irritating to skin

Toxicology

This material is a systemic poison and constitutes a serious health hazard. The risks of using it in the laboratory must be fully assessed before work begins. Acute poisoning by ingestion, inhalation or skin contact may lead to death. Phenol is readily absorbed through the skin. Highly toxic by inhalation. Corrosive and can causes burns. Severe irritant.

Personal protection

Person should wear safety glasses, gloves and work in good ventilation.

Symbol

Material Safety Data Sheet
Phenol MSDS

Section 1: Chemical Product and Company Identification

Product Name: Phenol

Catalog Codes: SLP4453, SLP5251

CAS#: 108-95-2

RTECS: SJ3325000

TSCA: TSCA 8(b) inventory: Phenol

CI#: Not available.

Synonym: Monohydroxybenzene; Benzenol; Phenyl hyroxide; Phenylic acid

Chemical Name: Carbolic Acid

Chemical Formula: C6H5OH

Contact Information:

Sciencelab.com, Inc.
14025 Smith Rd.
Houston, Texas 77396

US Sales: **1-800-901-7247**
International Sales: **1-281-441-4400**

Order Online: ScienceLab.com

CHEMTREC (24HR Emergency Telephone), call: 1-800-424-9300

International CHEMTREC, call: 1-703-527-3887

For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

Composition:

Name	CAS #	% by Weight
Phenol	108-95-2	100

Toxicological Data on Ingredients: Phenol: ORAL (LD50): Acute: 317 mg/kg [Rat]. 270 mg/kg [Mouse]. DERMAL (LD50): Acute: 630 mg/kg [Rabbit]. 669 mg/kg [Rat].

Section 3: Hazards Identification

Potential Acute Health Effects:
Very hazardous in case of skin contact (corrosive, irritant), of eye contact (irritant), of ingestion, of inhalation. Hazardous in case of skin contact (sensitizer, permeator). The amount of tissue damage depends on length of contact. Eye contact can result in corneal damage or blindness. Skin contact can produce inflammation and blistering. Inhalation of dust will produce irritation to gastro-intestinal or respiratory tract, characterized by burning, sneezing and coughing. Severe over-exposure can produce lung damage, choking, unconsciousness or death. Inflammation of the eye is characterized by redness, watering, and itching. Skin inflammation is characterized by itching, scaling, reddening, or, occasionally, blistering.

Potential Chronic Health Effects:
CARCINOGENIC EFFECTS: A4 (Not classifiable for human or animal.) by ACGIH, 3 (Not classifiable for human.) by IARC.
MUTAGENIC EFFECTS: Mutagenic for mammalian somatic cells. Mutagenic for bacteria and/or yeast.

TERATOGENIC EFFECTS: Not available.
DEVELOPMENTAL TOXICITY: Not available.
The substance may be toxic to kidneys, liver, central nervous system (CNS).
Repeated or prolonged exposure to the substance can produce target organs damage. Repeated exposure of the eyes to a low level of dust can produce eye irritation. Repeated skin exposure can produce local skin destruction, or dermatitis. Repeated inhalation of dust can produce varying degree of respiratory irritation or lung damage. Repeated exposure to a highly toxic material may produce general deterioration of health by an accumulation in one or many human organs.

Section 4: First Aid Measures

Eye Contact:
Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention immediately.

Skin Contact:
In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Cover the irritated skin with an emollient. Cold water may be used.Wash clothing before reuse. Thoroughly clean shoes before reuse. Get medical attention immediately.

Serious Skin Contact:
Wash with a disinfectant soap and cover the contaminated skin with an anti-bacterial cream. Seek immediate medical attention.

Inhalation:
If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.

Serious Inhalation:
Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. WARNING: It may be hazardous to the person providing aid to give mouth-to-mouth resuscitation when the inhaled material is toxic, infectious or corrosive. Seek immediate medical attention.

Ingestion:
Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. If large quantities of this material are swallowed, call a physician immediately. Loosen tight clothing such as a collar, tie, belt or waistband.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: May be combustible at high temperature.

Auto-Ignition Temperature: 715°C (1319°F)

Flash Points: CLOSED CUP: 79°C (174.2°F). OPEN CUP: 85°C (185°F).

Flammable Limits: LOWER: 1.7% UPPER: 8.6%

Products of Combustion: These products are carbon oxides (CO, CO2).

Fire Hazards in Presence of Various Substances:
Flammable in presence of open flames and sparks, of heat.
Non-flammable in presence of shocks.

Explosion Hazards in Presence of Various Substances:
Risks of explosion of the product in presence of mechanical impact: Not available.

Risks of explosion of the product in presence of static discharge: Not available.

Fire Fighting Media and Instructions:
SMALL FIRE: Use DRY chemical powder.
LARGE FIRE: Use water spray, fog or foam. Do not use water jet.

Special Remarks on Fire Hazards:
Phenol + nitrides results in heat and flammable gas generation.
Phenol + mineral oxdizing acids results in fire.
Phenol + calcium hypochlorite is an exothermic reaction producing toxic fumes which may ignite.

Special Remarks on Explosion Hazards:
Phenol + sodium nitrite causes explosion on heating.
Peroxydisulfuric acid + phenol causes explosion.

Section 6: Accidental Release Measures

Small Spill: Use appropriate tools to put the spilled solid in a convenient waste disposal container.

Large Spill:
Corrosive solid.
Stop leak if without risk. Do not get water inside container. Do not touch spilled material. Use water spray to reduce vapors. Prevent entry into sewers, basements or confined areas; dike if needed. Eliminate all ignition sources. Call for assistance on disposal. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

Section 7: Handling and Storage

Precautions:
Keep locked up.. Keep container dry. Keep away from heat. Keep away from sources of ignition. Empty containers pose a fire risk, evaporate the residue under a fume hood. Ground all equipment containing material. Do not ingest. Do not breathe dust. Never add water to this product. In case of insufficient ventilation, wear suitable respiratory equipment. If ingested, seek medical advice immediately and show the container or the label. Avoid contact with skin and eyes. Keep away from incompatibles such as oxidizing agents, acids.

Storage:
Air Sensitive. Sensitive to light. Store in light-resistant containers. Moisture sensitive. Keep container tightly closed. Keep container in a cool, well-ventilated area.

Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If user operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection:
Splash goggles. Synthetic apron. Vapor and dust respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

Personal Protection in Case of a Large Spill:
Splash goggles. Full suit. Vapor and dust respirator. Boots. Gloves. A self contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

Exposure Limits:
TWA: 5 (ppm) from ACGIH (TLV) [United States] SKIN
TWA: 19 (mg/m3) from ACGIH (TLV) [United States] SKIN

TWA: 5 from NIOSH [United States]
TWA: 19 (mg/m3) from NIOSH [United States]
TWA: 5 (ppm) from OSHA (PEL) [United States]
TWA: 19 (mg/m3) from OSHA (PEL) [United States]
TWA: 5 (ppm) [Canada]
TWA: 19 (mg/m3) [Canada]Consult local authorities for acceptable exposure limits.

Section 9: Physical and Chemical Properties

Physical state and appearance: Solid.

Odor:
Distinct, aromatic, somewhat sickening sweet
and acrid

Taste: Burning.

Molecular Weight: 94.11 g/mole

Color: Colorless to light pink

pH (1% soln/water): Not available.

Boiling Point: 182°C (359.6°F)

Melting Point: 42°C (107.6°F)

Critical Temperature: 694.2 (1281.6°F)

Specific Gravity: 1.057 (Water = 1)

Vapor Pressure: Not applicable.

Vapor Density: 3.24 (Air = 1)

Volatility: Not available.

Odor Threshold: 0.048 ppm

Water/Oil Dist. Coeff.: The product is more soluble in oil; log(oil/water) = 1.5

Ionicity (in Water): Not available.

Dispersion Properties: See solubility in water, methanol, diethyl ether, acetone.

Solubility:
Easily soluble in methanol, diethyl ether.
Soluble in cold water, acetone.
Solubility in water: 1g/15 ml water.
Soluble in benzene.
Very soluble in alcohol, chloroform, glycerol, petroleum, carbon disulfide, volatile and fixed oils, aqueous alkali hydroxides, carbon tetrachloride, acetic acid, liquid sulfur dioxide.
Almost insoluble in petroleum ether.
Miscible in acetone.
Sparingly soluble in mineral oil.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Heat, ignition sources (flames, sparks), light, incompatible materials

Incompatibility with various substances: Reactive with oxidizing agents, metals, acids, alkalis.

Corrosivity:
Extremely corrosive in presence of copper.
Slightly corrosive in presence of stainless steel(304), of stainless steel(316).
Non-corrosive in presence of glass, of aluminum.

Special Remarks on Reactivity:
Air and light sensitive. Prone to redden on exposure to light and air.
Incompatible with aluminum chloride, peroxydisulfuirc acid, acetaldehyde, sodium nitrite, boron trifluoride diethyl ether + 1,3-butadiene, isocyanates, nitrides, mineral oxidizing acids, calcium hypochlorite, halogens, formaldehyde, metals and alloys, lead, zinc, magnesium and their alloys, plastics, rubber, coatings, sodium nitrate + trifluoroacetic acid.
Phenol + isocyanates results in heat generation, and violent polymerization.
Phenol + 1,3-butadiene and boron trifluoride diethyl ether complex results in intense exothermic reaction.
Phenol + acetaldehyde resultes in violent condensation.

Special Remarks on Corrosivity:
Minor corrosive effect on bronze.
Severe corrosive effect on brass.

Polymerization: Will not occur.

Section 11: Toxicological Information

Routes of Entry: Absorbed through skin. Dermal contact. Eye contact. Inhalation. Ingestion.

Toxicity to Animals:
Acute oral toxicity (LD50): 270 mg/kg [Mouse].
Acute dermal toxicity (LD50): 630 mg/kg [Rabbit].

Chronic Effects on Humans:
CARCINOGENIC EFFECTS: A4 (Not classifiable for human or animal.) by ACGIH, 3 (Not classifiable for human.) by IARC.
MUTAGENIC EFFECTS: Mutagenic for mammalian somatic cells. Mutagenic for bacteria and/or yeast.
May cause damage to the following organs: kidneys, liver, central nervous system (CNS).

Other Toxic Effects on Humans:
Very hazardous in case of skin contact (corrosive, irritant), of ingestion, .
Hazardous in case of skin contact (sensitizer, permeator), of eye contact (corrosive), of inhalation (lung corrosive).

Special Remarks on Toxicity to Animals:
Lowest Published Lethal Dose:
LDL [Human] - Route: Oral; Dose: 140 mg/kg
LDL [Infant] - Route: Oral; Dose: 10,000 mg/kg

Special Remarks on Chronic Effects on Humans:
Animal: passes through the placental barrier. May cause adverse reproductive effects and birth defects (teratogenic) Embryotoxic and/or foetotoxic in animal. May affect genetic material (mutagenic).

Special Remarks on other Toxic Effects on Humans:

Section 12: Ecological Information

Ecotoxicity:
Ecotoxicity in water (LC50): 125 mg/l 24 hours [Fish (Goldfish)]. >50 mg/l 1 hours [Fish (Fathead minnow)]. >50 mg/l 24 hours [Fish (Fathead minnow)]. >33 mg/l 72 hours [Fish (Fathead minnow)]. >33 ppm 96 hours [Fish (Fathead minnow)].

BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

Toxicity of the Products of Biodegradation: The products of degradation are less toxic than the product itself.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:
Waste must be disposed of in accordance with federal, state and local environmental control regulations.

Section 14: Transport Information

DOT Classification: CLASS 6.1: Poisonous material.

Identification: : Phenol, solid UNNA: 1671 PG: II

Special Provisions for Transport: Not available.

Section 15: Other Regulatory Information

Federal and State Regulations:
Connecticut hazardous material survey.: Phenol
Illinois toxic substances disclosure to employee act: Phenol
Illinois chemical safety act: Phenol
New York release reporting list: Phenol
Rhode Island RTK hazardous substances: Phenol
Pennsylvania RTK: Phenol
Minnesota: Phenol
Massachusetts RTK: Phenol
Massachusetts spill list: Phenol
New Jersey: Phenol
New Jersey spill list: Phenol
Louisiana RTK reporting list: Phenol
Louisiana spill reporting: Phenol
TSCA 8(b) inventory: Phenol
TSCA 4(a) proposed test rules: Phenol
TSCA 8(a) IUR: Phenol
TSCA 8(d) H and S data reporting: Phenol: effective: 6/1/87; sunset: 6/01/97
SARA 302/304/311/312 extremely hazardous substances: Phenol
SARA 313 toxic chemical notification and release reporting: Phenol
CERCLA: Hazardous substances.: Phenol: 1000 lbs. (453.6 kg)

Other Regulations:
OSHA: Hazardous by definition of Hazard Communication Standard (29 CFR 1910.1200).
EINECS: This product is on the European Inventory of Existing Commercial Chemical Substances.

Other Classifications:

WHMIS (Canada):
CLASS D-1A: Material causing immediate and serious toxic effects (VERY TOXIC).
CLASS D-2A: Material causing other toxic effects (VERY TOXIC).
CLASS E: Corrosive solid.

DSCL (EEC):
R24/25- Toxic in contact with skin and if swallowed.
R34- Causes burns.
R40- Possible risks of irreversible effects.
R43- May cause sensitization by skin contact.
R52- Harmful to aquatic organisms.
S1/2- Keep locked up and out of the reach of children.
S24- Avoid contact with skin.
S26- In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
S28- After contact with skin, wash immediately with plenty of water
S37/39- Wear suitable gloves and eye/face protection.
S45- In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).
S46- If swallowed, seek medical advice immediately and show this container or label.
S56- Dispose of this material and its container at hazardous or special waste collection point.

HMIS (U.S.A.):

Health Hazard: 3

Fire Hazard: 2

Reactivity: 0

Personal Protection: j

National Fire Protection Association (U.S.A.):

Health: 4

Flammability: 2

Reactivity: 0

Specific hazard:

Protective Equipment:
Gloves.
Synthetic apron.
Vapor and dust respirator. Be sure to use an approved/certified respirator or equivalent. Wear appropriate respirator when ventilation is inadequate.
Splash goggles.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

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