REMOVAL OF HEAVY METALS FROM INDUSTRIAL WASTEWATER USING ACTIVATED CARBON

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ABSTRACT

The presence of heavy metals in wastewater is known to cause severe damage to aquatic life, beside the fact that these metals kill microorganism during biological treatment of wastewater with a consequent time delay of the treatment process. Chromium is one of the major heavy metals present in wastewater which has toxic effect and is a strong oxidizing agent capable of being absorbed through the skin. Palm oil mills in Malaysia produce about 4.3 million tones of shell and the significant problems in the palm fruit processing is managing the wastes generated during the process. The palm shell can be converted into useful products such as activated carbon. So, this method will reduce industrial wastewater problem and will bring benefits to society. Hence, this research aims to use activated carbon produced from palm shell to remove Chromium from industrial wastewater. Pyrolysis was applied for the preparation of activated carbon from palm shell using furnace at 600ºC. The treatment of activated carbon was carried out by oxidizing it with sulphuric acid and coating with chitosan. Two adsorbents namely Palm Shell Activated Carbon (PSAC) and Palm Shell Activated Carbon coated with Chitosan (PSACC) were used to remove chromium from aqueous solution. The effects of pH of the solution, adsorbent dosage, agitation speed, and contact time on adsorption of chromium were studied. The experimental results proved that the chromium removal efficiency of PSACC was better compared PSAC. Freundlich and Langmuir isotherms were used to analyze the adsorption of chromium from aqueous solution. The results concluded that Freundlich isotherm captured the adsorption of Chromium better compared to Langmuir isotherm as the former have higher correlation regression coefficient.

ABSTRAK

Logam berat yang hadir di dalam air kumbahan diketahui menyebabkan beberapa kerosakan kepada hidupan akuatik, di samping fakta yg menyatakan bahawa logam-logam ini membunuh mikroorganisma semasa rawatan biologi terhadap air kumbahan dengan akibat penundaan masa proses rawatan itu. Chromium adalah salah satu major logam berat yang hadir di dalam air kumbahan yang mempunyai kesan toksik dan mampu menyerap melalui kulit kerana merupakan ejen pengoksidaan yang tinggi. Minyak kelapa sawit di Malaysia menghasilkan 4.3 juta tan metrik kulit sawit dan masalah utama di dalam proses buah sawit adalah mengendalikan sisa-sisa yang terhasil semasa proses itu. Kulit sawit boleh ditukar kepada hasil yang berguna seperti karbon aktif. Jadi, kaedah ini akan mengurangkan masalah industri air kumbahan dan akan membawa kebaikan kepada masyarakat. Dengan itu, kajian ini bertujuan untuk menggunakan karbon aktif yang terhasil daripada kulit sawit, untuk menyingkirkan Chromium daripada industri air kumbahan. Pyrolisis akan digunakan untuk penyediaan karbon aktif daripada kulit sawit menggunakan dapur leburan pada suhu 600ºC. Rawatan karbon aktif dilaksanakan melalui pengaoksidaannya dengan asid sulfurik dan selaput menggunakan chitosan. Dua bahan penyerap iaitu Karbon Aktif Kulit Sawit (PSAC) dan Karbon Aktif Kulit Sawit dibalut dengan Chitosan (PSACC) digunakan untuk menyingkirkan Chromium daripada larutan. Kesan-kesan pH larutan, dos bahan penyerap, kelajuan dan masa terhadap penyerapan Chromium akan dikaji. Keputusan eksperimen membuktikan bahawa efisien penyingkiran Chromium daripada PSACC adalah lebih baik berbanding PSAC. Isoterma Freundlich dan Langmuir digunakan untuk menganalisis penyerapan Chromium daripada larutan. Keputusan menyimpulkan bahawa isoterma Freundlich adalah lebih baik daripada isoterma Langmuir kerana mempunyai hubungkait pekali regresi yang tinggi.

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LIST OF SYMBOLS

PSAC	-	Palm Shell Activated Carbon
PSACC	-	Palm Shell Activated Carbon coated with Chitosan
^{o}C	-	Degree Celsius
q_e	-	Amount of metal ions adsorbed
K_L	-	Langmuir equilibrium constant
K_F	-	Freundlich equilibrium constant
Ce	-	Solution phase metal ion concentration
AAS	-	Atomic Absorption Spectrometer
cm	-	Centimetre
mm	-	Millimeter
hr	-	Hour
min	-	Minute
g	-	Gram
mg	-	Milligram
L	-	Liter
ml	-	Milliliter
rpm	-	Revolution per minute
%	-	Percentage
E	-	Removal efficiency
C_0	-	Initial concentration
C_1	-	Equilibrium concentration

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Recently, heavy metal pollution around all factories has been pointed out with the expansion of the industries in developing countries (Morgan and Lee, 1997 and Brower *et al*., 1997). Wastewater from the all factories is divided into two types, which are from manufacturing process and from rinsing process (Gotoda *et al*., 1992; M.K.Denki *et al*., 1986). In advanced countries, removal of heavy metals in wastewater is normally achieved by advanced technologies such as precipitation–filtration, ion exchange and membrane separation (Tohyama *et al*., 1973). However, in developing countries, these treatments cannot be applied because of technical levels and insufficient funds. Therefore, it is desired that the simple and economical removal method which can utilize in developing countries are established. Although the treatment cost for precipitation–filtration method is comparatively cheap, the treatment procedure is complicated. On the other hand, adsorption method such as ion exchange and membrane separation is simple one for the removal of heavy metals. However, there is a limit in the generality in developing countries because chelating and ion-exchange resins are expensive. Therefore, it is worthwhile to develop the economical adsorbents to remove heavy metals which can be generally utilized in developing countries.

A heavy metal is a member of an ill-defined subset of elements that exhibit metallic properties, which would mainly include the transition metals, some metalloids, lanthanides, and actinides. Many different definitions have been proposed, some based on density, some on atomic number or atomic weight, and some on chemical properties or toxicity (John H. Duffus, 2002). The term ‘heavy metal’ refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), lead (Pb), zink (Zn), and copper (Cu). Heavy metals are natural components of the earth's crust. They cannot be destroyed. As trace elements, some heavy metals like copper, selenium and zinc are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning (Aremu, 2002).

A number of technologies have been developed over the years to remove heavy metals from industrial wastewater. The conventional chemical methods include precipitation, ion-exchange, electrochemical processes, ultra filtration, reverse osmosis and membrane technology (Abdel-Shafy *et al.*, 1996; Amuda *et al.*, 2006). A major disadvantage with precipitation is production of sludge. Ion exchange is considered a better alternative technique for remove heavy metals or such a purpose. However, it is not economically appealing because of high operational cost. Adsorption using commercial activated carbon can remove heavy metals from wastewater, such as Cd, Ni, Cr, Zn and Cu.

Activated carbon is one of the most important types of industrial carbon with very high porosity and surface area. It is prepared by carbonization and activation of a large number of raw materials of biological origin such as coconut shells, wood, peat, coal and fruit stones (Rodriguez and Linares, 1988; Rodriguez, 1997). In general, the raw materials to make activated carbon must accomplish a sort of requirements like high carbon content, low mineral content, easily activation, low degradation during storage, and, of course, low cost (Rodriquez, 1997). Agro-industrial by-products such as coconut shells, almond shells, hazelnut shells, cherry stones, eucalyptus, apricot stones, nuts, grape seeds, olive and peach stones, sugar cane bagasse and oil palm trunks are materials usually inexpensive and abundantly available for which the effective utilization has been desired (Guo and Lua, 2001; Hussein *et al*., 1996; Hayashi *et al*., 2002). Palm shells from palm oil processing mills are an agricultural solid waste in some tropical countries (Guo and Lua, 2001).

Palm shell is a good raw material for preparation and production of activated carbon (Nomanbhay *et al.*, 2005).

1.2 Problem Statement

Rapid industrialization has led to increased disposal of heavy metals into the environment. The tremendous increase in the use of the heavy metals over the past few decades has inevitably resulted in an increased flux of metallic substances in the aquatic environment. The metals are special because of their persistency in the environment. At least 20 metals are classified as toxic, and half of these are emitted into the environment in quantities that pose risks to aquatic life (Kortenkamp *et al.*, 1996). Chromium is one of the major heavy metals present in wastewater which has toxic effect and is a strong oxidizing agent capable of being absorbed through the skin. The sources of chromium mostly from chemical industry, paint, metallurgy, leather, fertilizers, petroleum refining and coal burning (Mishra, 2008). Chromium has both beneficial and detrimental properties. Two stable oxidation states of chromium persist in the environment, Cr (III) and Cr (VI), which have contrasting toxicities, mobilities and bioavailabilities. Whereas Cr (III) is essential in human nutrition (especially in glucose metabolism), most of the hexavalent compounds are toxic, several can even cause lung cancer. While Cr (III) is relatively innocuous and immobile, Cr (VI) moves readily through soils and aquatic environments and is a strong oxidizing agent capable of being absorbed through the skin (Park and Jung, 2001). Palm oil mill is one of the most important agro-industry in the Malaysia. Palm oil mills in Malaysia produces about 4.3 million tones of shell and the significant problems in the palm fruit processing is managing the wastes generated during the process (Diego et al., 2004). One possibility of managing the waste is to convert it into useful product such as activated carbon. This approach will reduce the problem of managing waste during palm fruit processing and also helpful in removing heavy metals from industrial wastewater.

1.3 Research Objective

The objectives of this study are as follows:

a) To prepare activated carbon from palm shell using pyrolysis process
b) To improve the adsorption capacity of palm shell activated carbon by coating with chitosan
c) To determine the optimum conditions for removal of Chromium from industrial wastewater
d) To find out suitable adsorption isotherm to capture the adsorption of Chromium using palm shell activated carbon

1.4 Scope of Research

The scopes of this study are as follows:

a) Activated carbon, which is prepared from low cost palm shell has been utilized as the adsorbent for the removal of heavy metals from industrial wastewater.
b) Chitosan is an excellent adsorbent and adsorption capacity of palm shell activated carbon can be improve by coating activated carbon with chitosan.
c) To study the effect of pH, adsorbent dosage, agitation speed and contact time on removal of chromium from an aqueous solution.
d) To study the adsorption phenomena using Freundlich and Langmuir adsorption isotherm.

1.5 Research Contribution (Significance of Study)

This research can help in minimizing the environmental impact and aid by removal of heavy metals from industrial wastewater. Whereas the present of heavy metals is strongly influence the human safety and health and of course environment factor. So the adsorbent such as activated carbon can be used to remove heavy metals from industrial wastewater to make the better safety and health life with good environment.

The significant of study for this project are as follows:

a) Aquatic environment

When wastewater containing heavy metals was discharged from industry, will create water pollution to aquatic environment. The aquatic ecosystem will also damage. So, this project will protect aquatic environment by the removal of heavy metals from wastewater.

b) Convert palm shell into useful products

Palm oil mills in Malaysia produces about 4.3 million tones of shell and the significant problems in the palm fruit processing is managing the wastes generated during the process. This palm shell can be converted into useful products such as activated carbon. So, this approach will reduce the problem of managing waste during palm fruit processing and also helpful in removing heavy metals from industrial wastewater.

c) Health concern

Industrial wastewater containing many heavy metals and most of the metals are emitted into the environment in quantities that pose risks to human health. Some of heavy metals can give advantages to human body, but, at higher concentrations they can lead to poisoning. So, removal of heavy metals from industrial wastewater is necessary to make sure good health for human and society.

d) Industrial purposes

Some industries, such as power-generation plants can use treated wastewater. A lot of water is needed to cool power-generation equipment, and using wastewater for this purposes means that the facility won't have to use higher-quality water that is best used somewhere else.

1.6 Thesis Layout

This thesis has 5 chapters. Chapter 1 introduces a background of the study and also about the problem of heavy metals whereas become an environment issues and the effects to human health and also the way to solve that problem. It is also includes research objective, scope and significance of study. Chapter 2 is about literature review which includes topic extensively researched of heavy metals, adsorption process with use palm shell activated carbon, activated carbon treatment and using of chitosan and also adsorption isotherm. Literature research contains information relevant and directly related to research in this study. In Chapter 3, the methodology develops the steps needed to study about preparation of activated carbon and the steps of removal of heavy metals will be discussed. Chapter 4 will be discussing about the results obtained from the experiment. It includes preparation of palm shell activated carbon, preparation of chitosan, the factor influencing adsorption process, and study of adsorption isotherm. Lastly Chapter 5 will provide some concluding remarks of this research and also provide recommendations on how to improve the heavy metals removal from wastewater.

CHAPTER 2

LITERATURE REVIEW

2.1 Heavy Metals

Water pollution by heavy metal and dyes remains a serious environmental problem nowadays. According to Mishra (2008), water pollution occurs when too much of an undesirable or harmful substance flows into a body of water, exceeding the natural ability of that water body to remove the undesirable material or convert it to a harmless form.

Industrial wastewater, which contains raw materials, processed chemicals, final products, processed intermediates, processed by-product and impurities of the industry (Mishra, 2008), can be classified as one of the sources of water pollution. Table 2.1 enlists the source of eight most common heavy metals that contribute to their appearance in water ways.

Table 2.1: Source of Eight Most Common Heavy Metals (Mishra, 2008)

No.	**Source**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Hg**	**Ni**	**Zn**
1.	Mining and ore processing	X	X			X	X		X
2.	Metallurgy	X	X	X	X	X	X	X	X
3.	Chemical Industry	X	X	X	X	X	X		X
4.	Alloys					X			
5.	Paint		X	X		X			X
6.	Glass	X				X	X		
7.	Pulp and paper mills			X	X	X	X	X	
8.	Leather	X		X			X		X
9.	Textiles	X	X		X	X	X	X	X
10.	Fertilizers	X	X	X	X	X	X	X	X
11.	Petroleum refining	X	X	X	X	X	X		X
12.	Coal burning	X	X	X	X	X	X	X	

2.2 Heavy Metals Removal

Various Chemical treatment methods have been developed for the removal and recovery of heavy metals from wastewaters. There are four major classes of chemical separation technologies: chemical precipitation, electrolytic recovery, adsorption/ ion exchange, and solvent extraction/ liquid membrane separation (Tohyama *et al.*, 1973). These major classes involves various methods include chemical treatment with lime, caustic oxidation and reduction, ion exchange, adsorption, reverse osmosis, solvent extraction, membrane filtration, electrochemical treatment and evaporative recovery. Chemical treatment methods for removal of heavy metals ions from waste are schematically illustrated in Figure 2.1. But most of these methods are often not economically viable especially when the effluents contain a large concentration of heavy metals (Bailey *et al.*, 1998). Most metal rich wastewater is treated by precipitation process. In this process, soluble metal ions are removed as insoluble metal hydroxide precipitates. But this process also has several disadvantages. The presence of aqueous organic ligands in wastewater can hinder metal hydroxide precipitation, which may result in residual metal concentrations that may no longer meet the increasingly stringent effluent discharge standards. The results are also not satisfactory with complex metals. Further, the major disadvantage with these treatment techniques is the production of sludge. As a result, an aquatic problem is changed into solid waste problem (Lewinsky, 2006). Comparison of the major features, advantages and disadvantages of chemical processes technologies for removal of heavy metal ion from wastewater are provided in Table 2.2.

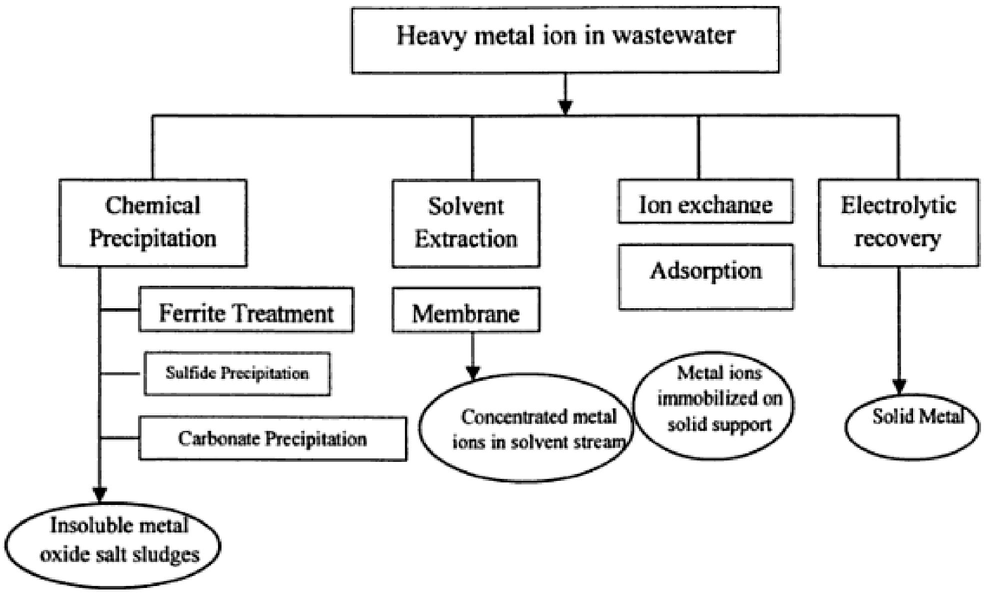

Figure 2.1: Available Chemical Treatment Methods for Hazardous Heavy Metals Ion Removal from Wastewater (Lewinsky, 2006)

Table 2.2: Comparison of Chemical Process Technologies for Heavy Metals Ion Removal

Process	Chemical/Energy Input	Major Advantages	Major Disadvantages	Refferences
Chemical precipitation	Precipitant/flocculant, acid, base, mixing and fluid handling	Low metal concentration in the effluent are achieved	High chemical requirement, sludge disposal problem	Stum *et al.*, 1970
Electrolytic recovery	Electrical energy	Lesser chemical consumption, recovery of pure metal is the added economic value	Energy intensive, high capital cost, reduced efficiency at dilute concentrations	Lewinsky, 2006
Adsorption/ Ion exchange	Fluid handling unit/ regenerating solution	Highly effective for removing metal ions to a very low concentration	Chemical regeneration requirement, fouling and corrosion of plant. Disposal of exhausted adsorbent.	Ghosh, 2006
Solvent extraction	Stripping solvent, makeup extraction solvent; fluid handling	Selective heavy metal removal, continuous concentrated metal solution recovery	Capital costs, toxic solvent discharges	Lewinsky, 2006
Membrane	Extractant for liquid supported membrane; fluid handling	Selective heavy metal removal	Fouling and lesser durability of membranes	Lewinsky, 2006

2.2.1 Chemical Precipitation

Chemical precipitation is the most common technique for the removal of heavy metals from water and wastewaters. The most frequently used chemicals for precipitation of metals are lime, caustic and sodium carbonates. The precipitation method has been used for the removal of iron, copper, zinc, tin cadmium and nickel from the effluents of metal finishing industries (Stum *et al*., 1970) and for removal of iron and aluminium in sewage water (Anon, 1978). In the process of lime precipitation of heavy metals, caustic is added usually to reach the ph of minimum solubility. This process has limitation where multiple metals present have a ph range of minimum solubility. The disadvantage of sulfide precipitation is that the sludge does not thicken well and sulphides are a potential odor and health hazard. Co-precipitation is another process where many metals are adsorbed on alum or iron floes but it has disadvantage of generating large quantities of sludge. For conclusion, chemical precipitation produces a large amount of sludge.

2.2.2 Solvent Extraction

Liquid-liquid extraction (also frequently referred to as solvent extraction) of metals from solutions on a large scale has experienced a phenomenal growth in recent years due to the introduction of selective complexing agents. In addition to hydrometallurgical applications, solvent extraction has gained widespread usage for waste reprocessing and effluent treatment. Solvent extraction involves an organic and an aqueous phase. The aqueous solution containing metal or metals of interest is mixed intimately with the appropriate organic solvent and metal passes into the organic phase. In order to recover the extracted metal, the organic solvent is contacted with an aqueous solution whose composition is such that metal is stripped from the organic phase and is reextracted into stripping solution. The concentration of the metal in the strip liquor may be increased, often 10 to 100 times over that of the original feed solution. Once the metal of interest has been removed, the organic solvent is recycled either directly or after a fraction of it has been treated to remove impurities (Lewinsky, 2006).

2.2.3 Membrane Process

Reverse osmosis is pressure driven membrane process in which a feed stream under pressure is separated into a purified permeate stream and a concentrated stream by selective permeation of water through a semi permeable membrane. Reverse osmosis enjoys wide spread popularity in the treatment of numerous diverse wastewaters. For example in the metal finishing industry, it is used for the recovery of plating chemicals from rinse water as well as purification of mixed wastewater to allow its reuse. Reverse osmosis has also been successfully demonstrated for the removal of Cr, Pb, Fe, Ni, Cu, and Zn from vehicle wash rack water (Lewinsky, 2006).

Electro dialysis is accomplished by placing cation and anion selective membranes alternatively across the path of an electric current. When the current is applied, the electrically attracted cations will pass through the cation exchanging membranes in one direction. The result is that salinity decreases between one pair of membranes increases between the next pair etc. Water can then pass through several such membranes until the required salinity is achieved. Dialysis involves the separation of solids by making use of unequal diffusion through membranes. The rate of diffusion is related to the concentration gradient, across the membranes (Lewinsky, 2006). The most commond problem of membrane process is fouling and lesser durability of membranes.

2.2.4 Ion Exchange

Ion exchange is a process in which ions on the surface of the solid are exchanged for ions of a similar charge in a solution with which the solid is in contact. Ion exchange can be used to remove undesirable ions from wastewater. Cations are exchanged for hydrogen or sodium and anions for hydroxide or chloride ions (Lewinsky, 2006).

2.2.5 Adsorption

Adsorption involves, in general, the accumulation (or depletion) of solute molecules at an interface (including gas-liquid interfaces, as in foam fractionation, and liquid-liquid interfaces, as in detergency). Adsorbent surfaces are often physically and/or chemically heterogeneous and bonding energies may very widely from one site to another. Adsorption involves accumulation of substance at an interface, which can either be liquid-liquid, gas-liquid, gas-solid or liquid-solid. The material being adsorbed is termed the adsorbate and the adsorbing phase, the adsorbent (Lewinsky, 2006). Major disadvantages for adsorption process is high cost for adsorbent. But, the solution is by using low cost absorbent such as palm shell activated carbon.

2.3 Adsorption Process

Adsorption is the accumulation of atoms or molecules on the surface of a material. This process creates a film of the adsorbate (the molecules or atoms being accumulated) on the adsorbent's surface. It is different from absorption, in which a substance diffuses into a liquid or solid to form a solution. The term *sorption* encompasses both processes, while desorption is the reverse process. Adsorption refers to the binding of molecules on the surface of solid material, i.e. an adsorption process involves the transfer of dissolved solutes from a liquid phase to the surface of an added solid phase which is also called adsorbent (Ghosh, 2006). The accumulation and concentration of pollutants from aqueous solutions by the use of biological materials, such as chitin, chitosan, yeasts, fungi or bacterial biomass, as adsorbent is termed biosorption (Crini, 2006).

Chemical adsorption results in the formation of a monomolecular layer of the adsorbate on the surface through forces of residual valence of the surface molecules. Physical adsorption results from molecular condensation in the capillaries of the solid. In discussing the fundamentals of adsorption it is useful to distinguish between physical adsorption, involving only relatively weak intermolecular forces, and chemisorptions, which involves, essentially, the formation of a chemical bond between the sorbate molecule and the surface of the adsorbent (Lewinsky, 2006). The general features, which distinguish physical adsorption, chemisorptions have been encapsulated in Table 2.3.

Table 2.3: Distinction between physical adsorption and chemisorptions (Lewinsky, 2006)

Physical Adsorption	Chemical Adsorption
Low heat of adsorption (<2 or 3 times latent heat of evaporation)	High heat of adsorption (> or 3 times latent heat of evaporation)
Non-specific	Highly specific
Monolayer or multilayer. No dissociation of adsorbed species. Only significant at relatively low temperatures.	Monolayer only May involve dissociation. Possible over a wide range of temperature.
Rapid, non-activated, reversible	Activated, may be slow and irreversible
No electron transfers although polarization of sorbate may occur	Electron transfer leading to bond formation between sorbate and surface

2.4 Adsorbents

Adsorbents are used usually in the form of spherical pellets, rods, moldings, or monoliths with hydrodynamic diameters between 0.5 and 10 mm. They must have high abrasion resistance, high thermal stability and small pore diameters, which results in higher exposed surface area and hence high surface capacity for adsorption. The adsorbents must also have a distinct pore structure which enables fast transport of the gaseous vapours. Most industrial adsorbents fall into one of three classes:

a) Oxygen-containing compounds – Are typically hydrophilic and polar, including materials such as silica gel and zeolites.

   Silica gel is a chemically inert, nontoxic, polar and dimensionally stable (< 400 °C) amorphous form of SiO_2. It is prepared by the reaction between sodium silicate and sulfuric acid, which is followed by a series of after-treatment processes such as aging, pickling, etc. These after treatment methods results in various pore size distributions. Silica is used for drying of process air (e.g. oxygen, natural gas) and adsorption of heavy (polar) hydrocarbons from natural gas.

Zeolites are natural or synthetic crystalline aluminosilicates which have a repeating pore network and release water at high temperature. Zeolites are polar in nature. They are manufactured by hydrothermal synthesis of sodium aluminosilicate or another silica source in an autoclave followed by ion exchange with certain cations (Na^+, Li^+, Ca^{2+}, K^+, NH_4^+). The ion exchange process is followed by drying of the crystals, which can be pelletized with a binder to form macroporous pellets. Zeolites are applied in drying of process air, CO_2 removal from natural gas, CO removal from reforming gas, air separation, catalytic cracking, and catalytic synthesis and reforming. Non-polar (siliceous) zeolites are synthesized from aluminum-free silica sources or by dealumination of aluminum-containing zeolites. The dealumination process is done by treating the zeolite with steam at elevated temperatures, typically greater than 500 °C (1000 °F). This high temperature heat treatment breaks the aluminum-oxygen bonds and the aluminum atom is expelled from the zeolite framework.

b) Carbon-based compounds – Are typically hydrophobic and non-polar, including materials such as activated carbon and graphite.

c) Polymer-based compounds - Are polar or non-polar functional groups in a porous polymer matrix.

Large number of adsorbents has been developed so far for the removal of inorganic. These include primarily activated carbon prepared from variety of materials of biological origin, industrial wastes, dead-biomass and organic wastes etc. Besides that several low cost adsorbents such as chitin, chitosan, clay, fly ash, peat, moss, zeolites, xanthates, seaweed/ algae/ alginate, lignin, bark/tannin rich material have also been explored for heavy metal containing wastewater (Lewinsky,