LEAD REMOVAL THROUGH THE ADSORPTIONS OF REACTIVATED CARBON

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CARBON

by

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DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled Lead Removal Through Adsorptions of Reactivated Carbon. I also declare that it has not been previously submitted for the award of any degree and diploma or other similar title of this for any other examining body or University.

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Witness by

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Date: 17 August 2022

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LIST OF SYMBOLS

°C   Unit of Temperature on Celcius Scale

g   Gram

kg   Kilogram

ml   Millilitre

l   Litre

M   Molarity

wt%   Weight Percentage

kV   Kilovolt

mA   Milliampere

nm   Nanometre

pA   Emission Current

X   Magnification Power

LIST OF ABBREVIATIONS

AC   Activated Carbon

SAC   Spent Activated Carbon

FAC   Fresh Activated Carbon

GAC   Granular Activated Carbon

PAC   Powdered ACTIVATED CARBON

RAC   Reactivated Carbon

AAS   Atomic Absorption Spectroscopy

SEM   Scanning Electron Microscope

UV-Vis   Ultraviolet-Visible Spectrometry

FTIR   Fourier-Transform Infrared Spectroscopy

ppm   Parts Per Million

rpm   Revolutions Per Minute

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ABSTRAK

Dalam kajian ini, prestasi penyingkiran logam berat menggunakan karbon teraktif semula (RAC) dan parameter terbaik untuk menyingkirkan logam berat menggunakan parameter berbeza telah berjaya disiasat. Karbon teraktif yang tepu (SAC) telah dijana semula dengan hemat dengan menggabungkan kaedah pengaktifan semula kimia dan haba. Ia dilakukan dalam mandi air pada suhu 85° C dengan Natrium Hidroksida (NaOH) sebagai ejen penjana semula. Kemudian, RAC pengaktifan semula haba dengan dimasukkan ke dalam relau selama 4 jam pada suhu 400°C. Sebelum dan selepas pengaktifan semula, SAC telah menjalani proses perawatan seperti prabasuh dan selepas basuh. Kemudian, RAC yang diperoleh telah digunakan dalam penjerapan logam berat (plumbum, Pb) secara berkelompok. Parameter yang berbeza telah dimasukkan untuk mendapatkan proses penjerapan yang optimum untuk penyingkiran Pb ion. Keputusan menunjukkan bahawa, peningkatan pH sekitar pH 4 hingga 6 mempunyai peratus penyingkiran Pb yang paling tinggi. Jisim RAC yang digunakan pada 3 g menunjukkan peratusan penyingkiran optimum. Kepekatan awal larutan logam berat juga menunjukkan bahawa 100 ppm mempunyai peratusan penyingkiran tertinggi pada 3 g RAC yang digunakan. Akhir sekali, masa rendaman selama 2 jam menunjukkan peratusan penyingkiran ion Pb yang paling tinggi.

ABSTRACT

In this study, performance of heavy metal removal using reactivated carbon and best parameters in order to remove the heavy metal using different parameters applied has been successfully investigated. Spent Reactivated Carbon (SAC) has been efficiently regenerated by combining chemical and thermal reactivation together. It was done in water bath at 85° C with the Sodium Hydroxide (NaOH) as the regenerant. Afterward, the Reactivated Carbon (RAC) undergone thermal reactivation by heating in furnace for 4 hours at 400°C. Prior and after reactivation, the SAC were undergone pretreatment process such as pre washed and post washed. Then, the RAC obtained has been used in the adsorption of heavy metal (lead, Pb) in batch. Different parameters have been incorporated to in order to obtained the optimized adsorption process for Pb removal. The results show that, increase in pH around pH 4 to 6 has the highest percent of Pb removal. The mass of RAC used at 3 g shows and optimum removal percentage. The initial concentration also shows that 100 ppm has the highest percentage of removal at 3 g of RAC used. Last but not least, contact time at 2 hours shows the highest removal percentage of Pb ions.

CHAPTER 1

INTRODUCTION

1.1 General Introduction

The worldwide population doubled in the last century, while global water consumption climbed sevenfold. The global water crisis will worsen as the population and economy of emerging nations grow; the world population is predicted to grow by over 40% in the next forty years, implying that residential, agricultural, industrial, and energy demands on water supplies will continue to rise (Pendergast & Hoek, 2011). According to the World Water Council, the number of people living in water-scarce areas would rise to almost 3.9 billion by 2030. The removal of heavy metals from polluted streams has become a serious environmental problem as a result of increased urbanization, industrialization, and agricultural activities. Many metals are needed nutrients in tiny levels, but at excessive concentrations, they constitute severe risks to the environment and human health. Heavy metals are non-biodegradable, which means they may build up in the environment and in living creatures (Hashim *et al.*, 2011)

The phrase "heavy metal" refers to a set of metals and metalloids that have an atomic density larger than 4000 kgm-3, or five times that of water, and are found naturally in the earth's crust. Although some of them are critical micronutrients for living organisms, they can cause serious poisoning at large doses. The most poisonous forms of these metals in their ionic species are the most stable oxidation states, such as Cd, Pb, Hg, Ag, and As ions in which they combine with biomolecules in the body

to generate very stable biotoxin compounds that are difficult to separate (Hashim *et al.,* 2011)

Efforts to minimize harmful heavy metals in water effluents have become one of the world's most pressing environmental concerns (Bohli *et al.*, 2015). Based on Bohli also, there are many conventional methods that have been applied to remove heavy metal from waste water but among all the other method such chemical precipitation, ion-exchange, adsorption, membrane filtration and electrochemical treatment technologies (Singh, Renu and Agarwal, 2017a)

In this case, adsorption method was chosen as the most practical and economical in the industries.

1.2 Problem Statement

Heavy metal pollution has become one of the most serious problems that the world may encounter nowadays. The heavy metal that are discharge from manufacturing industries and agriculture activities may run into waste water and natural water such as the river and end up to the waste water treatment. If the water is do not treated properly, the negative impact from the heavy metal is inevitable such as harming the living organism especially human health andimbalanced the natural ecosystem.

Studies shows heavy metal pollution in Malaysia generally by lead has become one of the major threats to the heavy metal pollution in Malaysia water. At the present time, there is a wide variety of options available for the removal of heavy metal ions from wastewater. Some of these options include coagulation flocculation, membrane filtration, flotation and chemical precipitation. However, some of these techniques result in the production of enormous amounts of slurry, which risk of metal ions being leached into the environment.

Recent study by (Da and Awad, 2017) stated that removal of heavy metal by adsorption of activated carbon is the most well-known water treatment adsorbent. This is mostly due to its porous nature, large surface area and low-cost materials such as coal, coconut shell, and wood. However, its applicability is still limited to copper metal and also due to the difficulty in optimized the reactivation of the spent activated carbon.

Therefore, this research will study about the performance using optimized reactivated carbon to remove the Lead, Pb with different parameters is applied to observed the effect of pH, contact time, initial concentration and amount of the RAC used.

1.3 Objectives

1. To study the performance of Lead, Pb metal ions removal using optimized reactivated carbon.

2. To obtain the best parameters in order to remove the heavy metal using different parameters such as pH, contact time, initial concentration and mass of RAC that will be applied.

1.4   Research Background

In this study, we study the effectiveness of chemical activation combined with thermal activation of SAC to produce RAC where NaOH was used as the regenerant solution followed by heating in furnace. SAC undergone pretreatment process involving pre washed prior the reactivation and post washed after the reactivation to optimized the

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RAC properties. Then, RAC produces were used as adsorbent to study the effectiveness of RAC in adsorption of heavy metal ions. Different parameters have been introduced such as initial concentration of heavy metal solution, pH values, contact time and mass of RAC used in order to study the best parameters to obtained the most optimized adsorption of heavy metal. Characterization techniques such as Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR) were performed to examined the properties of SAC and RAC in terms of chemically and physically. Ultraviolet-Visible Spectroscopy (UV-Vis) was used to study the optimum SAC's parameter in terms of waste water prior and after the reactivation step. Atomic Adsorption Spectroscopy (AAS) was used in adsorption test of heavy metal solutions by RAC with different parameters in order to determine the best removal efficiency of the heavy metal.

CHAPTER 2

LITERATURE REVIEW

2.1   Introduction

Industrialization of chemical industries has leads to discharging of high number of heavy metals such as zinc (Zn), lead (Pb), iron (Fe), copper (Cu), cadmium (Cd), nickel (Ni), chromium (Cr) and mercury (Hg) into the wastewater such the river, sea and lake (Liu and Huang, 2011).

Heavy metal contamination is mainly caused by waste streams from many sectors, such as mining, metal plating, battery manufacturing, paper manufacturing, and leather manufacturing, as well as pesticide use (Shan *et al.* 2020). Although some heavy metals, such as Zn, Cu, and Ni, are required by human bodies, they become poisonous when they exceed the safety limits. Industrial waste, agricultural pesticide and fertilizer waste, and urban garbage runoffs are the primary sources of water pollution, contaminating ground water and soil. Heavy metals can have harmful effects on human health and have negative ecological consequences, thus they must be removed from natural sources (Singh, Renu and Agarwal, 2017).

Due to their existence at trace amounts (ppb range to less than 10ppm) in diverse environmental matrices, heavy metals are also classified as trace elements. Physical parameters such as temperature, phase association, adsorption, and sequestration impact their bioavailability. Chemical parameters such as speciation at thermodynamic equilibrium, complexation kinetics, lipid solubility, and octanol/water partition coefficients also have an impact. Biological aspects including species traits, trophic relationships, and biochemical/physiological adaptability are also essential

(Tchounwou *et al.*, 2012)

Based on (Lim *et al.,* 2017), estuaries have a high richness of aquatic and wildlife creatures. Modernization and urbanization have steadily deteriorated the environmental health of estuaries. The kind of metals bound in the sediments has a significant impact on the degradation of estuarine health status. Several studies have recently been published that show hazardous metal ions are contaminating estuaries that are mostly released from anthropogenic activities.

Throughout the past decade, researchers in Malaysia have conducted a number of studies examining the heavy metal contamination found in a variety of areas across the country. An investigation was conducted into the water quality as well as the habitat appropriateness of a hemipteran population located upstream of the Kerian River (Ishadi *et al.,* 2014). They used three different types of heavy metals, but there were no water quality restrictions implemented. The presence of heavy metals was investigated by (Ibrahim *et al.* 2015) for a Riverbank filtration (RBF) system located upstream of the Kerian River. This research looked at the water from the river as well as the water from the pumping well. They found that the standard levels for iron and arsenic, out of 10 different heavy metals, were exceeded. These limits are set by the Malaysian Ministry of Health. The widespread application of pesticides in the agricultural region upstream of the Kerian River is the factor that should be considered the most likely culprit in this incident (Akhtar *et al.*, 2022)

Both anthropogenic and natural factors can release heavy metals into the environment. Mining activities are one of the main anthropogenic sources that contribute to emissions. The released metals can occasionally stay in the environment for a very long time after mining operations have ended (Duruibe, Ogwuegbu and Egwurugwu, 2007). Heavy metals are a major source of environmental contamination,

which is more pronounced in mining regions and around abandoned mine sites (Peplow, 1999). The metals are either carried as dissolved species in water or as a component of suspended sediments across rivers and streams. The water from underground sources, especially wells, may then get contaminated as they are then either held in river bed sediments or seep into the subterranean water. Some are also carried by natural disaster such as the wind of storm and flood, leading to a number of environmental issues (Duruibe, Ogwuegbu and Egwurugwu, 2007).

Since the heavy metals concentrations build up in sediments it will eventually make their way into the food chain. Consequently, has an impact on the ecological system and directly endangers human health. Heavy metal concentrations in the effluents harm river water and fish, leading to eventual serious health hazards and financial expenses for locals, including the polluters. Toxic heavy metals in this river must be continuously monitored over an extended period of time because they may eventually affect the fish that fishermen and communities eat (Poon *et al.*, 2016).

For Malaysia, its uses surface water for 99 percent of its household water needs, with groundwater providing the remaining 1 percent. About 580 km3 of water are projected to be available inside Malaysia each year, with 30 percent of that being used for municipal purposes. Drinking water was processed and provided to customers as tap water, bottled drinking water, and bottled mineral water mostly from surface water and groundwater sources (Ab Razak *et al.,* 2015).

To make wastewater effluent safe and palatable for living things, heavy metals including arsenic, lead, cadmium, chromium, zinc and other dangerous metallic contaminants must be eliminated. Water consumption is the main way that heavy metals enter the body. Even while our bodies require some heavy metals, excessive exposure to them can cause major health issues with the gastrointestinal tract, heart,

blood vessels, and central nervous system. It can also have an adverse effect on one's mental health. The permitted concentration limits for each heavy metal chosen as well as their effects on human toxicity are compiled in Table 2.1 below which are referred from WHO official website to the date (Nik Abdul Ghani *et al.,* 2021).

Table 2.1: Standard limit of selected heavy metals in drinking water (WHO, 2017)

Heavy metals contaminant	WHO guideline value (mg/L)	Effects on human health
Lead, Pb	< 0.05	damage to the developing fetal brain, renal, circulatory, and nervous system conditions
Arsenic, As	0.01	Carcinogen, toxic, cause cancer of the skin, lungs, liver and bladder
Cadmium, Cd	0.003	Carcinogen, vomiting, diarrhea. kidney disease, lung damage and fragile bones
Zinc, Zn	3	Stomach nausea, skin irritations, cramps, vomiting and anemia
Chromium, Cr	0.05	Extremely toxic, diarrhea, vomiting, pulmonary congestions, liver and kidney damage, irritation to the lining of the nose, nose ulcers, runny nose, asthma, cough, shortness of breath or wheezing.

2.2   Environmental studies

The industrial industry is thought to be the leading source of metal pollution in the environment. Metal finishing operations such as electroplating, etching, and metal component preparation for various industries have been recognized as a major source of wastes with high concentrations of Cd, Cu, Zn, Ni, Fe, Al, Zn, Mn, Cr, and Sn (Shazili *et al.,* 2006).

Heavy metal ions are removed using a variety of traditional processes, including chemical precipitation, ion exchange, lime coagulation, solvent extraction, reverse osmosis, and filtering. Adsorption has shown to be highly promising in the treatment of wastewater because it can successfully remove heavy metal ions at low concentrations where other approaches have failed in many circumstances (Saif *et al.*, 2015).

Heavy metal is deposited in sediments as a result of ongoing industrial, household, and agricultural waste flow into rivers and lakes. These contaminants include heavy metals will put people's health at risk after entering the food chain. Unlike the majority of organic pollutants, heavy metals cannot be degraded biologically (Parmar and Thakur, 2013).

Physical, chemical, and biological technologies are examples of conventional method as shown in figure 2.1. Whereas figure 2.2 depicts several of these techniques. Each of these approaches has their pros and cons, making them insufficient to address the wastewater treatment issue. The benefits and drawbacks some of the conventional approaches to metal removal are summarised in Table 2.2.
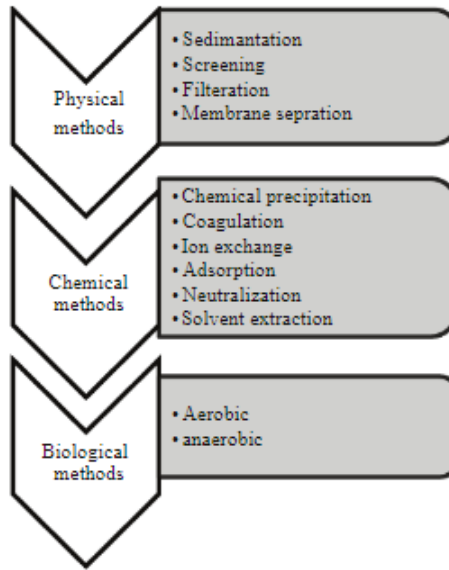
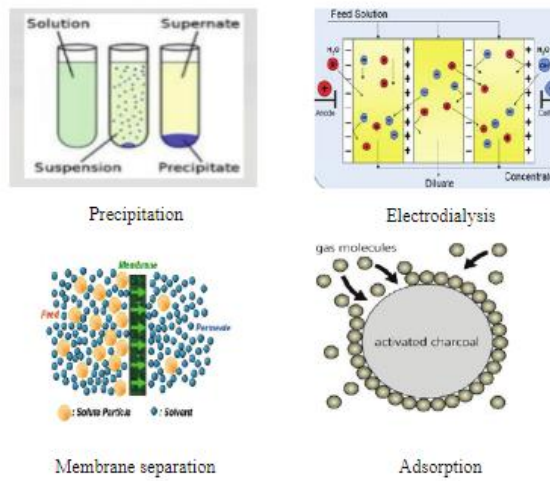Figure 2.1: Conventional methods in heavy metal removal (Raouf *et al.,* 2016)

Figure 2.2: Illustrations for some conventional methods for metal removal (Raouf *et al.,* 2016)

2.2.1 Chemical Precipitation

The conceptual mechanism of heavy metal removal by chemical precipitation is shown in the equation (Eq.) $M^{2+} + 2(OH)^- = M(OH)_2$, where $M(OH)_2$ is the insoluble metal hydroxide and M^{2+} and OH^- are the dissolved metal ions and precipitant, respectively. The primary factor that considerably enhances heavy metal removal by chemical precipitation is pH adjustment to the basic conditions (pH 9–11) (Barakat, 2011). employs alkaline to increase the pH of the solution to enable the precipitation of heavy metal hydroxide, which is then separated from the liquid using filtration or other solid/liquid separation techniques. Even though the chemical precipitation method for removing heavy metals is highly successful, the resulting heavy metal sludge is regarded as a hazardous solid waste and requires proper treatment. Heavy metal sludge treatment might occasionally be more challenging than heavy metal wastewater treatment (Budak, 2013).

2.2.2 Coagulation-flocculation treatment

Coagulation is process of destabilize colloid by nullifying the force that repels the particles apart. While flocculation is the aggregation of nullified particles. Aluminum, ferrous sulphate, and ferric chloride are common coagulants that are used to neutralise the ion charges. With the aid of a flocculant, such as polyaluminum chloride (PAC), polyferric sulphate (PFS), polyacrylamide (PAM), and other macromolecule flocculants, enormous agglomerates of particles are joined together to form a sedimentation as shown in fig 2.4 (Qasem *et al.,* 2021).
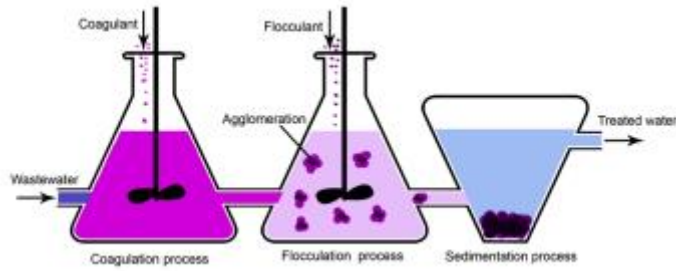
Figure 2.4: Schematic of the coagulation-flocculation treatment process (Qasem *et al.,* 2021).

One of the most crucial techniques for treating waste water is coagulation, however its primary targets are hydrophobic colloid and suspended particles made up of insoluble materials. The removal of soluble compounds from water using a coagulant is almost impossible. Heavy metal ions that are soluble in waste water are persistent contaminants. They can hydrolyze into particles or be adsorbed onto particles. Therefore, coagulation can somewhat lower the number of heavy metals in waste water (Chang *et al.,* 2007).

2.2.3 Ion Exchange

The ion exchange technique uses a reversible chemical process to swap out unfavorable metal ions for safe, eco-friendly ones. By bonding a heavy metal ion to an immobile solid particle and replacing it with the solid particle cation, a heavy metal ion is extracted from a wastewater solution based on figure 2.3 where the position of the metal ions, which are cations in wastewater, is similar to that of H^+ and Na^+ in ion exchange particles. This technique might potentially be used to eliminate anion. Solid ion-exchange particles can be made of organic resins or inorganic zeolites, which are both naturally occurring materials. Target heavy metal ions, such as Pb^{2+}, Hg^{2+}, Cd^{2+}, Ni^{2+}, V^{4+}, V^{5+}, Cr^{3+}, Cr^{4+}, Cu^{2+}, and Zn^{2+}, can be removed from wastewater using the ion-exchange approach which by some or all of them (Dąbrowski *et al.*, 2004).

The reaction below can be used to explain how the ion exchange mechanism for metal removals works. It involves an ion exchange particle that exchanges its cation (EC^+) with the wastewater cation (WC^+) using an ion exchanger of $M^- EC^+$ where M^- is the fixed anion and EC^+ is the exchange cation which are Na^+ and H^+ are frequently used as exchange cations (Qasem *et al.,* 2021).
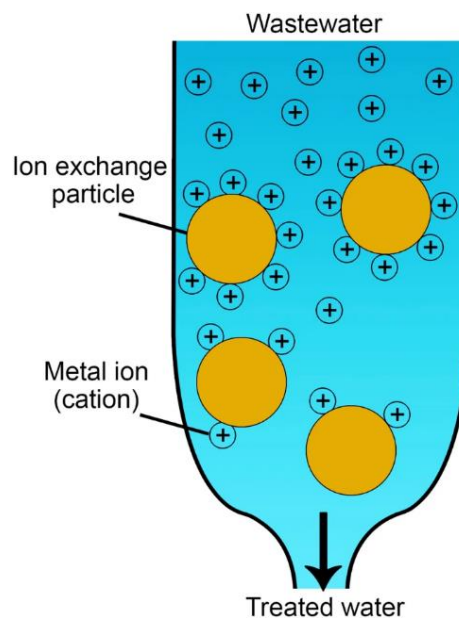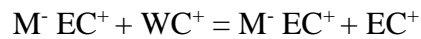
$$M^- EC^+ + WC^+ = M^- EC^+ + EC^+$$

Fig. 2.3: Schematic diagram of the ion exchange process (Qasem *et al.,* 2021).

2.2.4   Reverse Osmosis

In reverse osmosis (RO), pressure is used to push a solution through a membrane, which keeps the solute on one side while letting the pure solvent flow to the other. More specifically, it is the act of exerting pressure over the osmotic pressure

to force a solvent across a membrane from an area of high solute concentration to a region of low solute concentration. This is the opposite of the natural osmosis process, which occurs naturally when no external pressure is applied and involves the passage of solvent through a membrane from a region of low solute concentration to an area of high solute concentration (Bakalár *et al.,* 2009). When reversing the osmosis process, pressure must be applied to the system. That is the reverse osmosis procedure, which is the osmosis process in figure 2.5 (Algureiri *et al.,* 2016).
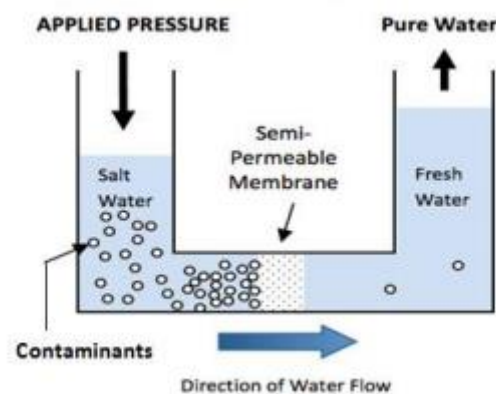
Figure 2.5: Schematic diagram of reverse osmosis process (Algureiri *et al.,* 2016)

2.2.5   Membrane Technology

Water and wastewater treatment membranes may be either porous or thin film composite (TFC). Microfiltration (MF), ultrafiltration (UF), and distillation are examples of low-pressure membrane processes; nanofiltration (NF) and reverse osmosis (RO) are examples of high-pressure membrane processes meanwhile, forward osmosis (FO) is an example of an osmotic-pressure-driven membrane process and electrodialysis (ED) and liquid membrane (LM) are examples of other membrane processes. Pore size, pore distribution, surface charge, degree of hydrophilicity, solution flow, and the presence of functional groups that aid in the separation process

are the primary aspects to consider when using membranes in aqueous environments. Both the water production rate and the efficiency with which heavy metals are removed from the water are directly related to these characteristics, making them crucial to the overall performance of the membrane. Scopus data shown in figure 2.6 indicates a dramatic increase in the use of membrane technology in water and wastewater treatment over the previous decade (Abdullah *et al.*, 2019).
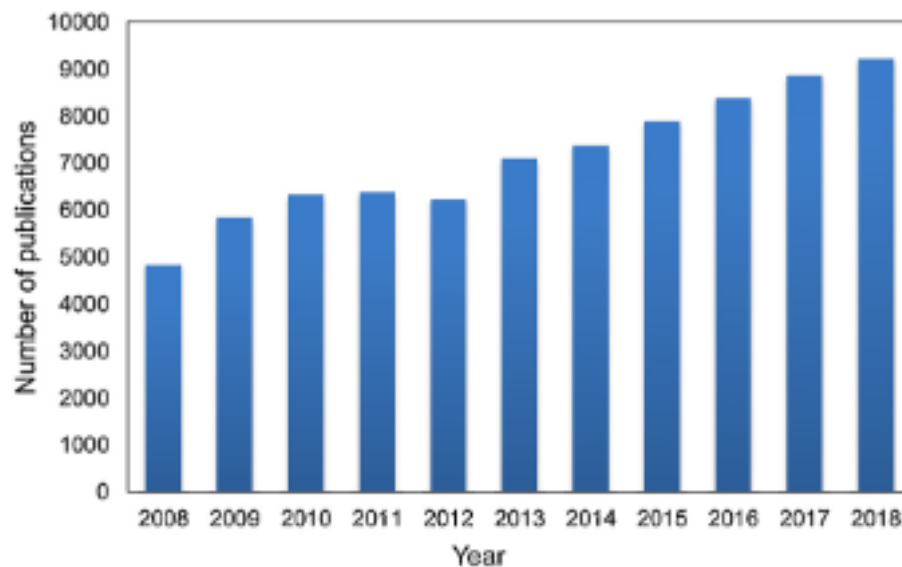
Figure 2.6: Number of publications on the membrane technology for water/wastewater

Treatment (Abdullah *et al.*, 2019)

A membrane, in concept, is a barrier that prevents the passage of certain unwanted components while allowing the passage of others. Permeate refers to the processed and collected streams, whereas retentate describes the rejected component. Selectivity and flow rate are often used to evaluate a membrane's efficiency. Flux is the rate at which a given volume of liquid passes through a given membrane in a given amount of time per unit of area of membrane. But selectivity refers to the amount of a material in a feed stream that a membrane must preserve. Size exclusion or steric hindrance mechanism, Donnan exclusion (charge-charge repulsion) effect, and the

capacity to adsorb certain contaminants all play a role in membrane separation's removal method, although these are far from the only ones. Figure 2.7 depicts, for many common membranes, the ways by which these unwanted substances are filtered out. Multiple mechanisms of partitioning may be involved in certain membrane-based activities (Abdullah *et al.*, 2019).
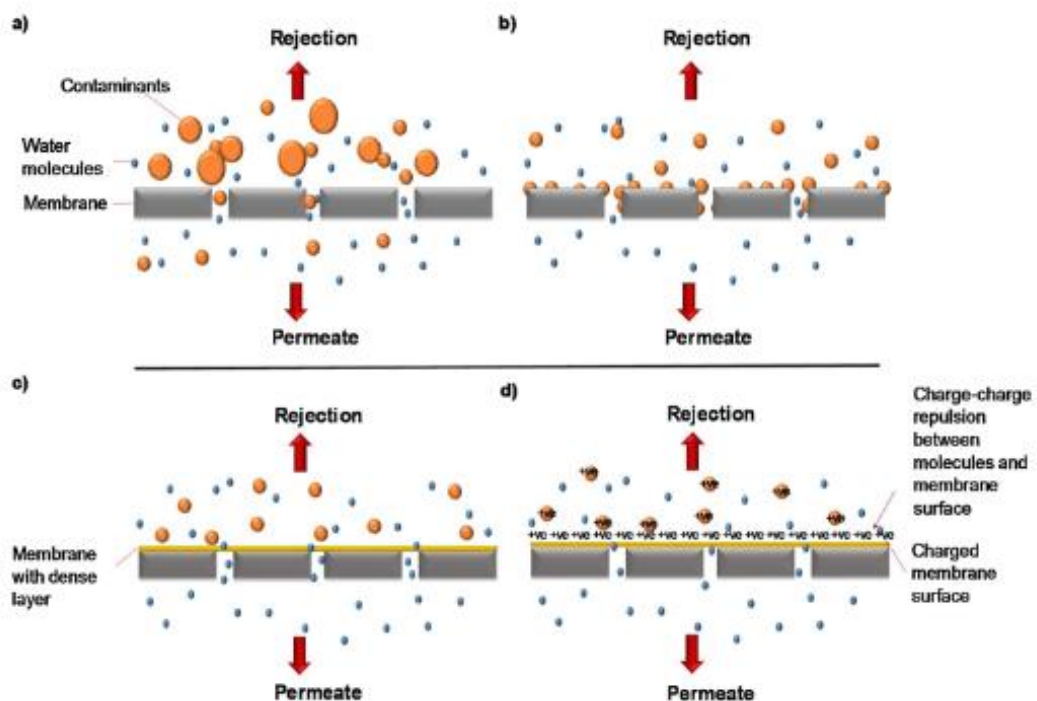

Figure 2.7: Removal mechanism by using membrane. (a) Size exclusion/steric hindrance mechanism by low pressure membrane; (b) adsorption by low pressure membrane; (c) size exclusion/steric hindrance mechanism by TFC membrane and; (d) Donnan exclusion/charge–charge repulsion by TFC membrane (Abdullah *et al.*, 2019).

Chemical precipitation, evaporation, ion exchange, electrochemical treatment, membrane technology and biological treatment are only some of the methods utilised to treat heavy-metal waste dissolved in water as can be seen in table 2.2. However, several obstacles were encountered when these technologies sought widespread implementation to deal with rising levels of soluble pollutants and the challenge of safely discarding their waste products. To use biological therapy as an example, its implementation was hindered by issues including cost, in-situ treatment failure, metal limitations, and the necessity to dispose of biological agents. Adsorption technology, on the other hand, has been used to manage both inorganic and organic waste, and it offers a number of benefits over competing methods in this area, including cheap cost, ease of application, efficiency, and effectiveness. Adsorption occurs when a substance serves as an adsorbent for pollutant molecules, either by forming chemical bonds with them or by interacting with them (Masindi & Muedi, 2018).

Table 2.2: Summary Comparison of current technologies used for heavy-metal removal (Fu and Wang, 2011).

Technology	Advantages	Disadvantages
Precipitation and Coagulation	Economically feasible, suitable for concentrations higher than 1000 mg/L	Requires a large amount of chemicals, slower removal process high sludge production, and formation of large particles
Adsorption	Flexibility and simplicity of design, economically feasible, ease of operation and insensitivity to toxic pollutants	Requires the regeneration of adsorbent materials

Membrane Technology	High rate of removal of heavy metals	Expensive, pores are easily blocked by fouling, high sludge production as insoluble matter.
Ion exchange	Good removal of a wide range heavy metal	Adsorbents require regeneration or a disposal process, can't handle concentrated metal solutions, nonselective and highly dependent on pH
Biological Treatment	Feasibility in removing some metals	Only feasible for removing some metals. Disposal of biological agent required

2.3   Adsorption Process

Adsorption is a mass transfer process in which chemicals accumulate at the interface oftwo phases, such as liquid–liquid, gas–liquid, gas–solid, or liquid–solid (Grassi *et al.,* 2012).

The adsorbate is the material that is being adsorbed, while the adsorbent is the substance that is being adsorbed. Atoms near at the surface of solids, such as activated carbons, have uneven forces relative to those within the solids, and foreign molecules are drawn to the surface to compensate for this imbalance. On the solid's surface, these molecules (adsorbates) create a monolayer (adsorbent) (Manocha, 2003).

Adsorption occurs in one of three ways which are diffusion, surface chemical reactions such as ion exchange, or surface complexation. Pore diffusion, surface diffusion, or a hybrid model of the two mechanisms are used to characterize diffusion

processes where external boundary layer film resistance is typically included in these models. Depending on the adsorbate–adsorbent functional group order of reaction, different kinetic models are available for chemical surface reactions including pseudo-first-order, pseudo-second-order, Elovich, Avrami and Bangham models (Singh, Renu and Agarwal, 2017).

On a large scale, adsorption has always been utilised as a purification and separation method mostly in industries. Organic chemicals such as dyestuffs, phenolics, endocrine-disrupting compounds, pesticides, medicines and many metal ions have demonstrated outstanding removal capabilities using highly porous adsorbents with exceptional selectivity, such as activated carbon. based on figure 2.8 and 2.9 below, the adsorption takes place in three steps. First, on the external surface will be adsorbed by adsorbate. Next, the adsorbate will move to the sites which has the highest adsorption potential energy. Last but not least, the interior pore wall of the activated carbon will be filled with nano porous adsorbate materials. All process mostly depends on several factors for example the surface area, pores volume, chemical structure and surface functional group.
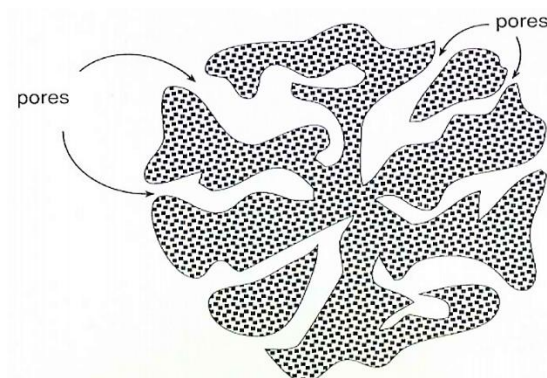

Figure 2.8: Typical carbon particle that has numerous pores that provide a

large

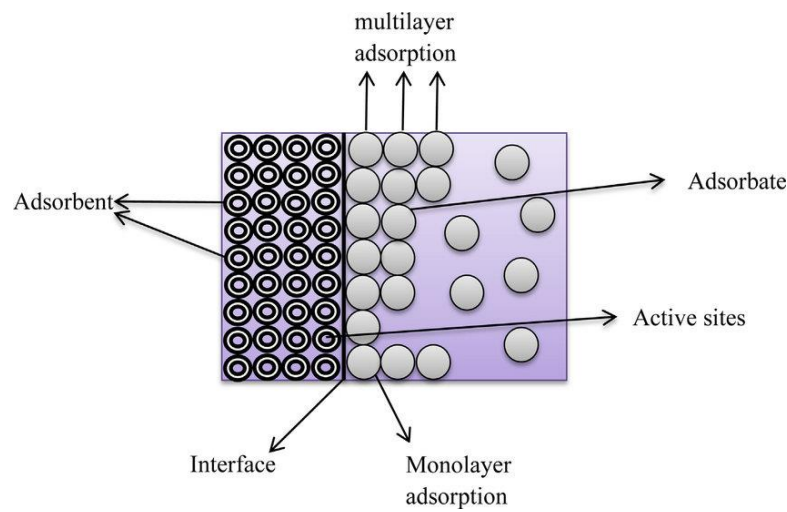surface area adsorption process (Chobanian *et al.*, 2003)

Figure 2.9: Schematic Diagram of a Surface Adsorption Process (Soliman

and Moustafa, 2020)

Adsorbents are made up of a variety of ingredient primarily in charge of removing any specificimpurities from wastewater (Grassi *et al.,* 2012). Natural and synthetic adsorbents are generally classed based on their origin. Clays, minerals, charcoal, ores, and zeolites are examples of natural adsorbents. Synthetic adsorbents are made from industrial wastes, agricultural wastes, and waste sludge, among other things (Ojedokun and Bello, 2016).

Adsorption has been shown to be an effective and cost-effective method of removing heavy metals, organic contaminants, and colours from contaminated streams. Activated carbon, silica, and graphene are some of the adsorbents that may be used in water purification. Adsorbent such as activated carbon has been found to be a good adsorbent for removing a wide range of organic and inorganic pollutants from the aquatic environment (Karnib *et al.,* 2014).

2.4   Activated Carbon

In order to replace bone char in the sugar refining sector, modern companies started producing active carbon in 1900–1901, and the first commercially available powdered activated carbon was made in Europe in the early 19th century using wood as a raw material. Any substance with a high carbon concentration can be used to create activated carbon. Given that it has a well-developed porous structure and a large internal surface area for adsorption process (Renu *et al.,* 2017). But, since coal -based activated carbon are highly in price, the use of the materials has been limit and further research has been conducted to convert any agriculture waste to undergo activation process to make activated carbon. For example, by using apricot stone (Kobya *et al.,* 2005), coconut button (Anirudhan *et al.,* 2011), rubber wood sawdust (Karthikeyan et al. 2005), palm shell (Saifuddin *et al.,* 2005), chickpea (Cicer arietinum) husks (Özsin *et al.,* 2019) and etc.

The two main processes in the synthesis of AC are carbonisation and activation. In general, carbonisation process effectively removes non-carbon elements, i.e. hydrogen, oxygen, nitrogen and various other volatile organic compounds from the precursor, leaving behind the carbon mass and basic pore structure. These initial pores are typically small and are often blocked by disorganised carbon (Bansal and Goyal, 2005). Subsequent to the carbonisation process, the carbonised precursor is subjected to activation through either physical activation, chemical activation or a combination of both. The activation process broadens the existing basic pore structure by burning out the pore walls while removing disorganised carbons which were initially blocking the pores (Hameed et al., 2009).

Physical activation requires high temperatures as compared to chemical

activation. Chemical activation generally involves reagents such as sulphuric acid, phosphoric acid, hydrochloric acid, zinc chloride (acids), potassium hydroxide, sodium hydroxide and sodium carbonate (bases) (Hayashi et al., 2002). These reagents act as dehydrating agents, causing pyrolytic decomposition of volatile compounds in a precursor. Chemical activation results in better pore development compared to physical activation. Strong bases for activation are corrosive, expensive and often hazardous, while zinc chloride causes problem to the environment (Lillo Ródenas et al., 2007). Thus, the selection of less harmful reagents such as inorganic acids should be explored. In this project, the acids used are sulphuric, nitric, phosphoric, acetic and citric acid,

Activated carbon is a porous substance having a large surface area and a high porosity. The carbon element accounts for more than 90% of activated carbon. Activated carbons have a large surface area and various surface functional groups such as carboxyl, carbonyl, phenol,quinone, lactone as present in table 2. They are attached to the margins of the graphite-like layers as shown in figure 2.10. As a result, they're thought to be good adsorbents for removing heavy metal ions (Deliyanni *et al.,* 2015).
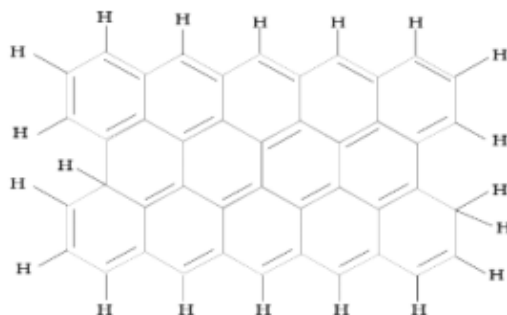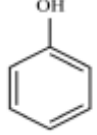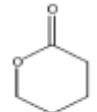

Figure 2.10: Molecular structure of activated carbon in graphite layer like

(Moosavi *et al.*, 2020)

Table 2.3: Schematic of Activated Carbon Functional Groups (Moosavi *et al.*, 2020)

Functional groups	Structure	Properties
Hydroxyl	R —— OH	Tends to make things more soluble in water -Polar -Hydrophilic
Carboxyl		-Acidic -Charged (-)
Carbonyl		-Charged (+) -Polar
Phenol		The hydroxyl groups are strongly activating and connected to a carbon in benzene ring
Lactone		Can't be hydrolyzed even at high temperature

Oxygen-containing functional groups such as carbonyl, carboxylic, lactone, and phenol are often associated with acidic surface characteristics and have a significant impact on the arrangement and size of primary crystallites generated in carbonaceous adsorbents. According to the literature, the concentration of oxygen-containing groups present on the surface plays a vital function since these atoms significantly boosted the adsorption capacity. Furthermore, hydrogen bond interactions between hydroxyl functional groups boost adsorption capacity (Moosavi *et al.*, 2020).

Carbonyl and carboxylic functional groups also improved AC adsorption performance by lowering Henry's constant values resulting in stronger affinity between the adsorbent and adsorbate (Moosavi *et al.*, 2020).

Activated carbon is a flexible adsorbent that is used in a wide range of applications in the environmental, industrial, and other industries for the removal,

recovery, separation, and modification of a wide range of species in liquid and gas-phase applications. Activated carbon'sporous surface is responsible for the adsorption of a variety of solutes and gases. All pores contain walls and two types of surfaces, an interior (microporous) surface and an exterior (non-porous) surface (Çeçen, 2014).

Depending on its shape and particle size, there are several varieties of AC which are Granular activated carbon (GAC), powdered activated carbon (PAC), pellet form as shown in figure 2.11. Meanwhile, cloths of activated carbon fibres (ACFCs), carbon nanotubes (CNTs) and monoliths are shown in figure 2.12 (Salvador *et al.,* 2015).

Figure 2.11: Picture of Granular activated carbon (GAC), powdered activated carbon (PAC) and AC in pellet form (Copper And Zinc Coated Activated Carbon [online], 2022)