DEVELOPMENT OF UV LIGHT AND WATER FILTERING SYSTEM DURING FLOODING EVENT

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By

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ABSTRAK

Disebabkan oleh pembangunan yang pesat, terdapat banyak aktiviti ekonomi yang dilakukan dalam pembangunan negara. Aktiviti-aktiviti yang dilakukan telah membawa kepada banyak jenis pencemaran terutamanya pencemaran air sungai. Hal ini kerana, kesemua aktiviti tersebut akan menggunakan sumber air untuk melakukan kerja mereka dan akhirnya air tersebut akan dilepaskan ke dalam sungai. Pencemaran selalunya mengandungi variasi organik dan juga bukan organik yang mana selalunya akan melebihi had yang dibenarkan standard air minuman. Untuk mengurangkan atau merawat pencemaran tersebut, kajian mengenai penggunaan penjerap untuk air sungai sudah dikaji selama bertahun. Tetapi, antara kajian-kajian tersebut, tiada lagi data pembangunan penjerap yang menggunakan karbon teraktif (AC) dan batu kapur (LS) yang disambungkan dengan sinaran UV dalam merawat air. Dalam kajian ini, penjerap disintesis untuk penjerapan warna dan kekeruhan, manakala sinaran UV disintesis untuk perawatan E.coli di dalam air sungai. Keberkesanan penjerap adalah dikaji. Kajian mengenai model isoterma juga ditentukan dan pada bahagian akhir, kajian mengenai turas dasar tetap juga dilakukan. Dalam kajian ini, sampel diambil daripada Sungai Kerian dimana ianya diambil pada tiga bahagian sungai tersebut, iaitu di hiliran, tengah, dan di hulu. Kemudian, pencirian untuk setiap bahagian dibuat dan ianya tidak sesuai untuk diminum. Keputusan telah dikenal pasti, daripada dos penjerap batu kapur, peratusan tertinggi kecekapan penyingkiran untuk warna dan kekeruhan dikenal pasti pada 76% dan 89%. Manakala untuk dos penjerap karbon teraktifperatusan tertinggi kecekapan penyingkiran untuk warna dan kekeruhan dikenal pasti pada 37% dan 61% masing-masing. Untuk penjerapan model isoterma, Langmuir model isoterma didapati sesuai dengan data penjerapan keseimbangan. Berdasarkan lengkung terobosan, titik terobosan untuk warna dan kekeruhan adalah masing-masing kurang daripada 60 minit.

ABSTRACT

Due to the rapid growth of development, there are many economic activities carried out in order to develop the nation. The activities done has led to many type of pollutant especially river water pollution. This is because, all of the activities will use the water resources to do their work and it will discharge to the river at last. The pollution usually contains variations of the organic and also inorganic pollutants which always exceed the permissible limit of drinking water standard. In order to reduce or treat the pollutants, the applications of adsorbents for river water have been studied for years. But, among the studies, there is no data available on the development of adsorbent from activated carbon (AC) and limestone (GLS) combined with the UV light in treating water. In this study, the adsorbent were synthetized for the adsorption of Colour and turbidity while the UV light was synthetized for the treatment of the E.coli in the river water. The effect of the adsorbent dosage was investigated. The study about the suitable model of isotherm also been covered and at the last part, the study of fixed-bed column was done. In this study, the sample was collected from Kerian River which has been taken at three parts of the river, at the downstream, middle and also the upstream. Then, the characterization for each of the part was done and it needs further treatment to be used as drinking water. The results have been identified, from the adsorbent dosage of limestone, the highest percentage of removal efficiency for Colour and turbidity was determined at 76% and 89%. While for the adsorbent dosage of activated carbon, the highest percentage of removal efficiency for Colour and turbidity was determined at 37% and 61% respectively. For the adsorption isotherm model, it has been defined that the Langmuir isotherm model was found well fitted to the equilibrium adsorption data. Based on the breakthrough curve, both of the breakthrough point for Colour, turbidity and e.coli for both adsorbent were less than 60 minutes respectively.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Malaysia is a country that experience flood yearly. Flood is one of a natural disaster that can bring the destruction and loss to the country. Usually, flood is happening because of the improper drainage condition which has not been built properly during the rainfall season and it has also happened because of the new development. When flooding is happening, it can give an effect to many things that include a quality of groundwater. This is because, rain would form a surface runoff and it will carry all the pollutants into the area of water retention and groundwater and the entire water in the aquifer will be contaminated (Saeed and Attaullah, 2014)

Groundwater plays an important role towards human use. So, if it is contaminated, it will create a difficult situation towards flood victim to acquire clean water during flood events. Based on the statistical use of groundwater globally, it is recorded that groundwater is a source the human use about 40% of it for drinking water, about 97% of village residents use groundwater for drinking purposes, and about 30-40% use for agriculture purposes (Sharma and Reddy, 2004).

Water played a very important role especially for human. So, in our developing country, clean water must be provided adequately. This is because, if the provided water is polluted, it can create water borne disease like diarrhoea, typhoid fever, hepatitis A and leptospirosis. In 2004, due to unsafe water and lack of basic sanitation, diarrhoea have been contributes to the death of 1.5 million children aged less than five year (World health Organization, 2004).

This study involved a method of UV light, activated carbon and also the limestone to treat flood water. Before treating the water, the characterization needs to be done to know the quality of the water. It is included the BOD, COD, Turbidity, Colour (Nguyen et al., 2018), Suspended Solid, pH, temperature and also E. coli.

1.2 Problem Statement

Flooding is a common disaster that always happened in the world. Flood can be categorized as a natural disaster that can happen because of the climate change and it is also can happen because of the human activities. When flooding is happening, it will affect groundwater. Groundwater is an important to human life. Usually, human will use the groundwater for drinking and agriculture use. When flooding is happening, the groundwater will be polluted. Groundwater pollutants are a big problem in many countries (Bhatnagar and Sillanpaa, 2009).

Moreover, the future risk from flooding is likely to increase prior to the impacts of evolving flood patterns and rapid urbanization that put more individuals in the manner of harm (MONRE, 2011). Women are one of the communities in society that become particularly prone to the impact of flooding because they often experience social, cultural, financial and political disadvantages as well as legal status and possibilities (CSRD, 2015). These socio-cultural conditions can even contribute to greater mortality rates among women during floods, and greater poverty rates owing to greater unemployment ad absence of fundamental freedoms. Furthermore, women's experience more psychological stress during and after a disaster owing to the role of women caretaker as part of the family (Bubeck P et al., 2018).

From the previous research, in a six year period between 2011 and 2016, more than 380 disease outbreaks related to waterborne protozoa were documented globally (Efstratiou et al., 2017). Other than that, 87% of total global mortality cases has attributed to the diarrhoea came from South Asia and Sub-Saharan Africa (Troeger et al., 2017). Therefore, it is not impossible that poor water supply and poor sanitation systems are the root cause that leads to these public health issues (Yang et al., 2012).

For this research, an absorption used where UV light, Activated Carbon and Limestone in order to see the availability of this absorption to treat the water. Kerian River was chosen as the water sample to be studied and the main parameter need to be studied were Turbidity, Colour and also E. coli.

1.3 Objectives

The overall aim of the study was to treat the flood water during flooding events by using the UV light, activated carbon and also limestone in order to release the best quality of water to the consumer to use in their daily life.

The study was carried out to fulfil several objectives as below:

1. To design water filtering system using UV light, activated carbon and limestone.
2. To study the efficiency of UV light to treat flood water.
3. To propose the water filter system to be used during flood event.

1.4 Scope of Work

This research is focused on the treatment of the flood water by using the combination of an adsorbent which are Activated Carbon and Limestone and the UV light. The removal is more focussed on removing three types of characterization which are Colour, Turbidity and also E. coli. The percentage of removal was determined after the treatment was done by using each of the removal. Lastly, the total pollutant removals can be determined.

1.5 Significance of Study

The outcome of the study is to propose the new design of a water filtering system in order to improve the existing water treatment from the discharge. Other than that is to see the efficiencies of the design during flood events. Furthermore, the result of the experiment will give a benefit to flood victim in order to obtain clean water. In addition, by developing this new product, it helps to achieve balance between environmental sustainability and also the economic sustainability. Lastly, the treatment will be resulting in getting a maximum of removal efficiency.

1.6 Dissertation Outline

The thesis has been categorized into specific chapters for better viewing and understanding of the study. This dissertation consists of five chapters.

Chapter 1: Introduction – this chapter gives an overview of the thesis, followed by the problem statement to identify, and understand why this research was carried out and its

relevance to current times followed by the objectives of this research in order to set the desired target of work, scope of work and finally the significance of this research.

Chapter 2: Literature Review – this chapter includes the review of previous studies regarding the water treatment technologies and the adsorbent material. This chapter also explains the details on the isotherm and fixed-bed column studies.

Chapter 3: Methodology – this chapter represents the experimental works, and all the procedures done in this research. It also includes the materials and equipment used for the experiment.

Chapter 4: Results and discussions – in this chapter, it provides all the results and discussion done for the experiments. It includes the sample characterization, one factor at a time, then, followed by adsorption isotherm and lastly fixed-bed flow studies. All the data were represents in terms of graphs and tables.

Chapter 5: Conclusion and recommendations – in this chapter, all the conclusion from the studies were made and it followed by the recommendations for future works based on the research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter consists of three sections. The first section discussed about the background of flooding events including the impact of the flooding. The second section consists of the characteristics of the water. Lastly, the third section is about the filtering system and it is elaborate about the absorption used in this study.

2.2 Background of flooding event

Flooding is presumably the most widespread weather hazard around the globe. It can eventually happen almost anywhere. A flood is defined as water to land that is generally clear. Flooding is often regarded as a result of heavy rainfall, but flooding can take place in a number of ways that are not directly related to ongoing weather events. A complete description of flooding must somehow include processes that have little or nothing to do with extreme weather. Although, it is clear that the water implicated in the flooding has fallen there sometime, perhaps ages ago, like a rainfall. Consequently, the origins of flooding ultimately lie in atmospheric processes that otherwise generate precipitation think regardless of what specific event the flood tends to cause (Doswell, 2003).

Even if the flood waters were directly caused instead by precipitation, atmospheric processes can be recognized as primarily responsible for the event. In other words, there are heavy rains that far exceed the average values for the area

affected. Only if the precipitation exceeds the average, the dry land can be affected which flood can happened. The amount of rainfall required for floods cannot therefore be defined in absolute terms. A precipitation event that causes a flood in one place may well be within the boundaries of what is typical for another place. In general, the flood-producing rainfall threshold increases as the region's average annual rainfall increases (Doswell, 2003).

Other than floods directly caused by rainfall, there are many ways in which precipitation can cause flooding, perhaps long after it has fallen. When water flows through the construction of dams, there is a risk that somehow the dams will fail. Such continuous releases of stored water can be destabilizing, manifesting itself as an extremely large ' wall of water, ' suffocated with sediment. Several other flood scenarios can develop along the shorelines of the world's oceans and even with huge freshwater lakes. Tsunamis, typically caused by underwater earthquakes and landslides, can flood the shorelines with huge waves breaking on the shallow waters near the shore. Storms of all kinds, including tropical cyclones, can lead the waters into storm surges before the winds flood the shore when the storms are near the land. Large lakes can experience at least flooding on their shores due to seiche, which are water surges (frequently oscillating) within enclosed water bodies. Seiche can be apparently caused by tornadoes or atmospheric processes (Doswell, 2003).

There are two types of flood that have been recognized which are flash flood and also river flood. Flash floods are categorized as a flood occurrence where the rapid rise in water occurs either during or within a few hours of the precipitation that causes the increase. Therefore, flash floods occur in small basins, where the sewerage basin's reaction time is short. Many other hydrological considerations are relevant to the phenomenon of a flash flood, for example human habitation, soil type, terrain gradients

and so on. Next is river flood. River flood is unlike flash floods, it is typically take place over days or sometimes even months. This is because they eventuate in large basins with ' main stem ' rivers. Hydrological variables often make a significant contribution to a river flood, but river floods may not be as sensitive to them all as flash floods. River floods are usually the result of a stagnant weather pattern on a synoptic scale. Fragmented heavy rainfall incidents occur many times for a total of days or even months, each actually contributing its share of precipitation to the tributaries, which further discharge into the main stem of a river (Doswell, 2003).

2.2.1 Impact of the flooding towards human health and environment

Climate change is a concerning issue for community engagement in certain region of the country. Uncertainty in meteorological criteria leads to an asymmetry of environmental components. Anthropogenic activities significantly affect the climate system of planet Earth because of the large amount of information from different greenhouse gasses into the atmospheric layer. The long-term resumption of these processes can act as a major factor for the unstable condition of atmospheric pressure, humidity, temperature, rainfall, and net vaporization. Temperature modification and rainfall volatility are strongly correlated. In some regions, rainfall variables often lead to floods and drought hazards (Rakib et al., 2017). Today, capitalist and socialist countries are massively affected by climate change. Water stress and floods are expected to increase during this century due to the impact of climate change (Ebi and K.Bowen, 2016).

The flooding hazard is one of the major causes of the social crisis, as it can specifically worsen the socioeconomic status of local communities. Among rural communities, children, women and disabled people have more previous experience

with flood-related hazards and the risks associated with them, as well as unwanted input at the local level (Rakib et al., 2017). The impact of water itself can be ruinous on structures and inanimate objects within them: books, furniture, photographs, electronic equipment, and so on. Simply by immersing them in water, even if they are not specifically damaged by the flow of water.

In addition, floodwaters generally contain suspended silt and potentially toxic microorganisms and dissolved chemical substances. This means that floods usually jeopardize the supply of drinking water, leading to short-term shortages of drinking water, with the additional long-term costs of restoring drinking water to residents of a flooded area. The mud and debris left behind when floodwaters recede can be costly to clean up and also pose a health risk, especially when the bodies drowned wild and domesticated animals in the debris are floating in the water. During the flood period, health facilities were most commonly affected. During this period, various waterborne diseases such as diarrhoea, cholera, jaundice and skin-related health problems are most commonly seen.

In particular, children and the elderly are most often affected by these types of health problems. Flood is staid that affects the health of the pregnant mother. The pregnant mother could not get any kind of health facilities during the flood. During the flood, the water is contaminated by various bacteria and poisonous substances so that the water could be harmful to human health, but it is bound to use this water in various daily activities because of the lack of safe water.

Other than that, when flood event occur, it also give an impact towards the environment. It can be a positive impact and also less positive impact. As for positive impact, flooding is a natural ecological process that plays an integral part in ensuring biological productivity and diversity in the flood plain (WMO, 2006). The less positive

impact is because it can cause environmental degradation. The biggest and most complicated to repair environmental harm usually occurs in developed areas in the floodplain. Flood can give the direct impact to the Wildlife and Livestock Health and Well-being. Flooding can affect the lives and well - being of wildlife and animals. Large amounts of water can directly impact natural and agriculture and farming habitats. For example, after the 2011 floods in Queensland, Australia, thousands of animals died as a result of water inundating their habitats (Dumas and Daisy, 2011).

In addition, flooding also affect in the dispersal of nutrients and pollution. Flood water may contain debris, pollutants and nutrients. Debris can also include trees and stones or even houses. Pollutants in flood water, such as bacteria and pesticides, can be transported away. Sedimentation and turbidity can eventually lead to the growth of algae and phytoplankton blooms, which impede water quality.

2.3 Characteristic of water

The quality of water is of main concern to mankind since it is directly related to human wellbeing. Water quality characteristics in aquatic environments emerge from a multitude of physical, chemical and biological interactions. The water bodies, such as rivers, lakes, and estuaries, are constantly shifting in terms of their geological age and geochemical characteristics. This dynamic balance of the aquatic system is easily disturbed by human activities leading to pollution, which propagates substantially as a fish kill, provocative taste, and body odour. The physicochemical behaviours of the water body directly impact the forms and production of aquatic plant life (Arora, 2017).

Clean and safe fresh water is essential for the preservation of all living things and the smooth operation of habitats, communities, and economies. Water quality

relates to the basic physical, chemical and biological characteristics of water, which determine its viability for life or human use.

2.3.1 Physical Characteristic

Physical characteristic are such as senses of touch, sight, smell and taste that can easily be determine. For example, temperature by touch, Colour, floating debris, turbidity and suspended solids by sight, taste and smell (Arora, 2017).

2.3.1.1. Temperature

Temperature is a measurement of the average (kinetic) energy of water molecules. It is defined on a linear scale of degrees Celsius or Fahrenheit. Temperature is a fundamental parameter of water quality. It determines the suitability of water for various forms of aquatic life. Temperature affects the quantity of water quality criteria, such as dissolved oxygen, which is a chemical characteristic. Oxygen conductivity in warm water is less than cold water.

The temperature in water bodies usually follows the average daily air temperature. It affects the amount of oxygen which can be dissolved in water, the rate of photosynthesis by algae and other aquatic plants, the metabolic rate of organisms, the specificity of organisms to toxic waste, parasites and diseases, and the timing of reproduction, migration and aestivation of aquatic organisms (Arora, 2017).

2.3.1.2. Colour

Colour in water is mainly a consideration for water quality for aesthetic reasons. Colour water tends to be unsuitable to drink, even though the water is generally safe for public use. The colour of water may due to the presence of organic substances, such as

algae or humid compounds. In recent times, colour has been used as an empirical assessment of the presence in water of potentially dangerous or toxic organic materials. Colour is important as most water users, whether domestic or industrial, normally prefer colourless water. The colour determination can help to estimate the costs of water discolouration (Arora, 2017).

2.3.1.3. Turbidity

Turbidity is a measure of the light-transmitting properties of water and consists of suspended and colloidal material. It is important today for health and aesthetic reasons. Regulation of natural water bodies is affected by human activity, the decay of plant matter, algal blooms, suspended sediments and plant nutrients. Turbidity offers an affordable estimate of the total suspended solids (TSS) concentration. It has little significance except in completely clear waters but is useful in describing drinking water quality in water treatment (Arora, 2017).

2.3.1.4. Solids

Solids are categorized as settling solids, suspended solids and filterable solids. Settle able solids (silt and heavy organic solids) are the ones that settle under the effect of gravity. Suspended solids and sortable solids are classified on the basis of particle size and the retention of suspended solids on standard glass-fibre filters. The importance of suspended solids in water is good on a number of bases. In fact, the solids can comprise of algal growth leading to severe eutrophic conditions in any water body. They reduce light absorption into surface waters and impede with aquatic plant life. The deposition of these on the beds of rivers and lakes may lead to septic and objectionable conditions and may detect the presence of unsatisfying wastewater effluent discharges (Arora, 2017).

2.3.2 Chemical characteristic

The health concerns associated with chemical components of drinking water tend to arise primarily from the ability of chemical composition to cause adverse health effects after prolonged exposure. There are several chemical constituents of water that can lead to health issues resulting from even a short exposure. A perceivable number of serious health concerns may happen as a result of the chemical contamination of drinking water (Arora, 2017).

2.3.2.1. pH

The pH is a measure of how acidic or fundamental (alkaline) water is. It is defined as the negative log of the ion concentration of hydrogen. The pH scale is logarithmic, ranging from 0 (very acidic) to 14 (very alkaline). The range of natural pH in fresh waters expands from around 4.5 in acidic, peaty upland waters to over 10.0 in waters with intense photosynthetic behaviour by algae. The most commonly experienced range is 6.5-8.0. The pH range suitable for fisheries is termed to be 5.0-9.0, although 6.5-8.5 is preferable. Alterations in pH may change the concentrations of other stimulants in water to a more toxic form. Ammonia toxicity, chlorine disinfection efficiency, and metal solubility are all prone to change in the pH value (Arora, 2017).

2.3.2.2. Dissolve Oxygen (DO)

Dissolved oxygen is the amount of gaseous oxygen (O_2) absorbed into an aqueous solution. It enters the water by dispersion from the surrounding air, by aeration (rapid movement) and as a waste material of photosynthesis. The oxygen in dissolved form is required by most aquatic life to continue growing. The lack of enough oxygen in water can result in the death of adults and juveniles, a decrease in growth, a failure eggs/larvae to survive, and a change in species present in a given water body. The

hypoxic condition in the water body (DO < 3mg / L) induces reduced cell growth and disrupts the circulatory fluid balance in the aquatic system, sooner or later leading to death (Arora, 2017).

2.3.2.3. Chemical Oxygen Demand (COD)

COD determines the quantity of oxygen needed to oxidize the organic matter present in the water body under precise oxidizing agent conditions, temperature and time. COD is an important water quality parameter, as it offers an index to evaluate the effect of wastewater discharged on the receiving environment. Higher COD levels actually represent a larger amount of oxidize organic material in the sample, the degradation of which will again lead to hypoxic situations in the water body. The ratio of BOD to COD implies the percentage of organic material in water that can be degraded by natural microorganisms in the environment (Arora, 2017).

2.3.3 Biological Characteristic

2.3.3.1. E.coli

E. coli is a bacterial species found in the faecal matter of warm-bloodied animals (humans, other mammals, and birds). Total coliform bacteria are a whole group of bacterial species that are relatively similar to and include species E. coli. The majority of faecal coliform cells discovered in faecal matter are E.coli. Untreated sewage, poorly preserved septic systems, untreated pet waste and farm animals with direct access to water bodies can lead to high levels of faecal coliform bacteria to appear and make the water harmful (Arora, 2017).

2.4 Type of filtering system for flood treatment

When it comes to flood, there is plenty of polluted water than clean water, and water sources are not approved for use. This is because; there are many kinds of waterborne pathogens that can also contribute diseases to death if the water is not treated well before use. By defining the size of the smallest bacteria, it is easier to find filtration based on the size of filter pores and other procedures to ensure that all bacteria are eliminated and water is safe to use (Nurul Aini Kamarudin et al., 2018).

It has become an issue to produce clean water, especially for drinking in the event of a flood. Furthermore, health risk becomes much more serious if the polluted floodwater can enter the water supply system through leaking pipes. There are many types and innovations nowadays for filtering dirty water into clean water. Although the result is as predicted as it is clear physically, but most of them are not safe to drink because some bacteria are still alive.

Some treatment has been investigated or handled to purify the floodwater into clean water and safe for drinking or cooking. For some countries that are exposed to flood disasters, the purification water system must be ready to prevent any disease for the victim. One of the treatments is by electrolysis, which oxygen ion was used to disinfect water, hydroxyl and hydronium to move the liquid (flood water) from one electrode to another. They respond with it chemically to eliminate the bacteria and turn the floodwater into clean water (Nurul Aini Kamarudin et al., 2018).

Another treatment has been implemented in Indonesia, which faced many potential flood disasters with a clean water problem, is MSWT, Mobile Surface Water Treatment. It was such a modular process, with a mixture of existing technologies and literature in a compact design and equipped with mobile functionalities for simpler

operation. The technology used is microfiltration (MF) or ultrafiltration (UF) for filtration, followed by UV lamps for microorganism disinfection (Ananto et al., 2013).

2.4.1 Water filter

A water filter is a device that destroys impurities from water by means of a fine physical barrier, chemical process and/or biological process. Water filters have evolved a lot in the last few years. Distillation is probably the strongest water purification method. Water is heated to boiling first. Filtration operates completely on particle or droplet size (and to a certain extent on the form), so that particles under a certain size pass through the barrier, while larger particles are attained on or in the barrier for later removal (Sutherland, 2008). However, it is difficult to find a portable water filter where customers can carry it anywhere and use that for more than one intent. So, for this experimental study, the portable water filter system was designed by using an Activated Carbon, Limestone and also UV light.

2.5 Types of Adsorbent

Adsorbents utilized in water treatment are obtained from natural origin and industrial production or activation method. A key characteristic of adsorbents could be expanse since sorption is a surface method. The big surface area is obtained by adopting materials that have a high range of pores within the interior material. While a high degree of porousness among the adsorbent granules additionally contributes to an efficient adsorbent that adsorbs into an enormous quantity of interior area onto which sorption method takes place (Howe et al., 2012).

There are many sorts of low price of adsorbent applied in adsorption and these types are the major type used in treatment of leachate, industrial wastewater and

groundwater for example like coconut shell, activated carbon and limestone. In addition, composite adsorbent additionally shows sensible performance in sorption method. In this study, the adsorbent used was limestone and activated carbon.

2.5.1 Granular Activated Carbon (GAC)

Activated carbon is a unique and versatile adsorbent but is also commonly used to remove unpleasant odour, Colour, taste, and other organic and inorganic contaminants(Bansal and Goyal, 2005). Activated carbon is a form of carbon that has been digested to make it particularly porous and therefore has a greater surface area available for adsorption or chemical reaction. Adsorption is a restoration process in which particles are bound to an adsorbent particle surface either by chemical or physical affection. It is most efficient in the removal of organic pollutants and other particles from water. Activated carbon also eliminates water taste, odour and Colour problems.

Most importantly, activated carbon filtration removes chlorine from the water, where chlorine is widely used as a disinfectant in water treatment. In addition, activated carbon removes certain organic chemicals such as trihalomethanes (THM), pesticides, industrial solvents (halogenated hydrocarbons), polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs). Activated carbon is not adequate for removal of suspended biological material. It can be done in a component that combines adsorption and biological activity (Sutherland, 2008).

In addition, large - scale applications for activated carbon will only increase the operating costs of a treatment plant due to the expensive cost of activated carbon over the years (Ali, 2010). Therefore, the disadvantages of commercially activated carbon

have led to a growing research interest seeking low cost alternative precursors for activated carbon as cheaper and renewable are the patterns among scientists in recent years. The selection of various activated carbon based waste products also aims to reduce a large number of waste materials, such as low cost activated carbon (Garg et al., 2004).

2.5.2 Granular Limestone (GLS)

Limestone would be an effective natural geological material for the treatment of heavy metals in polluted water. In addition, the limestone from northern Tunisia, comprising higher contaminants such as silica and iron and aluminium oxides, shows better removal efficiency than the limestone of the southern region (Sdiri et al., 2012). Limestone is an alkaline medium and a low - priced material compared to the price of activated carbon because of its abundant nature. However, the adsorption capability of limestone is lower than the activated carbon. Limestones have mostly helped to remove heavy metals such as arsenic (III) and iron more efficiently through the filtration process (Devi et al., 2014). Limestone has the ability to be a low efficient adsorbent in water treatment.

2.6 Disinfection

Ultraviolet (UV) filtration is one of the most prevalent and most effective water and wastewater disinfection technologies (Song et al., 2016). UV disinfection is considered environmentally friendly as a non - corrosive form of treatment free of disinfectant residues and product disinfection (Liberti et al., 2003). In Southern Italy, UV disinfection was successful in eliminating protozoan parasites for unrestricted reuse of municipal wastewater in agriculture without the composition of by-products for

disinfection (Liberti et al., 2003). UV disinfection has also shown high efficiency in Catarina, Brazil, in disinfecting secondary swine effluent for water reuse under alkaline - controlled conditions (Bilotta et al., 2017).

UV light emitting diodes (UV - LEDs) have recently been considered as a potential new UV source with functionalities that could resolve the shortcomings of these lamps, including high reliability, robust designs, lower voltage criteria and lack of mercury(Chevremont et al., 2013). Ultraviolet disinfection is not totally free of inconvenience. Wastewater components such as solid particles, humid acid, and turbidity can decrease the inactivation efficiency of the UV disinfection process due to absorption, dispersion, and protective effects (Carre et al., 2018).

2.7 Adsorption Isotherm

Isotherm is an important thing to explain the relationship between the adsorbate and also the adsorption process. By using the isotherm analysis, the important parameter of the adsorbent which is the adsorption capacity can be identified. Adsorption isotherm is the amount of solute adsorbed per unit weight of the adsorbent as function of equilibrium concentration in the bulk solution at constant temperature. The examples of data plotted as adsorption isotherm are shown in Figure 2.1. From the figure, q, kg adsorbate (for solute) / kg adsorbent (for solid) is known as the concentration in the solid phase while c, kg adsorbate/m^3 fluid is known as concentration in the fluid phase (liquid or gas). For the description of adsorption data, Langmuir and Freundlich adsorption is the most commonly used.

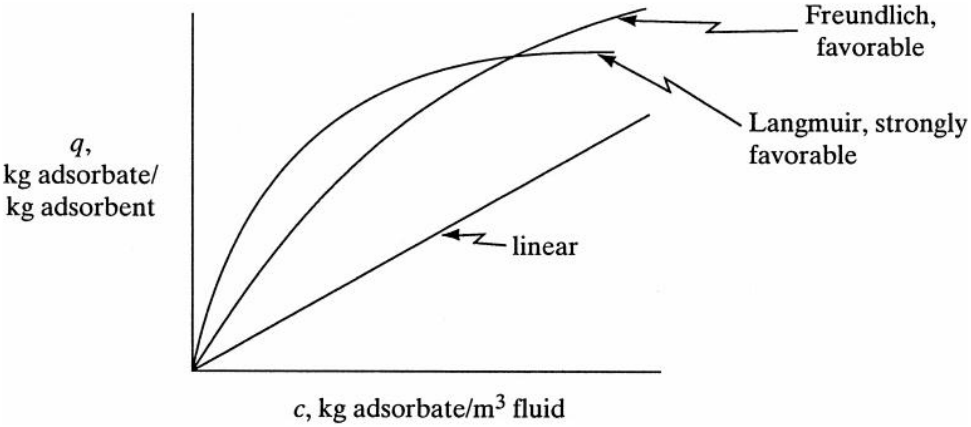

Figure 2.1: Common types of adsorption isotherm (Geankoplis, 2003)

2.7.1 Langmuir isotherm

Langmuir isotherm is advanced on the idea that the adsorption procedure happens at particular homogeneous sites inside the adsorbent surface with uniform distribution of energy level. Essentially, once the adsorbate is connected at the site, no in addition adsorption can take place at that site (Mohd Din et al., 2009). The Langmuir equation is expressed as the following equation (Itodo et al., 2011):

$$q_e = \frac{q_m K_L C_e}{1 + K_L C_e} \tag{2.1}$$

Table 2.1 below shows four types of linear form can be expressed from general Langmuir equation (Itodo et al., 2011).

Table 2.1: Types of linear version derived from general Langmuir equation(Itodo et al., 2011)

Type	Equation	
1	$\frac{C_e}{q_e} = \frac{1}{K_L q_m} + \left(\frac{1}{q_m}\right) C_e$	(2.2)
2	$\frac{C_e}{q_e} = \left(\frac{1}{K_L q_m}\right) \frac{1}{C_e} + \frac{1}{q_m}$	(2.3)
3	$q_e = q_m - \left(\frac{1}{K_L}\right)\left(\frac{q_e}{C_e}\right)$	(2.4)
4	$\frac{q_e}{C_e} = K_L q_m - K_L q_e$	(2.5)

Where C_e is the equilibrium concentration of the adsorbate (mg/L), q_e is the amount of adsorbate adsorbed per unit mass of adsorbent (mg/g), q_m is the maximum monolayer adsorption capacity of the adsorbent (mg/g) and K_L is the Langmuir adsorption constant with respect to the free energy adsorption (L/mg). The intercept value can be used to calculate the Langmuir's constant.

2.7.2 Freundlich Isotherm

Freundlich isotherm is an empirical equation assuming that the adsorption process takes place on heterogeneous surfaces (Benhouria et al., 2015) as in the following equation:

$$q_e = K_F C_e^{1/n} \quad (2.6)$$

Where q_e is the amount of adsorbate adsorbed at equilibrium (mg/g), C_e is the equilibrium concentration of adsorbate (mg/L), K_F is the Freundlich constant (mg/g)(L/mg)$^{1/n}$ and n is the Freundlich heterogeneity factor. The linear form of are shown in Equation 2.7:

$$logq_e = logK_f + \frac{1}{n} logC_e \quad (2.7)$$

Based on linear graph of log q_e vs log C_e obtained, the value of 1/n can be derived from the slope of the graph and the y axis intercept will give Freundlich constant.

2.8 Fixed-Bed Column Studies

Batch, continuous moving bed, continuous fixed bed (up flow or down flow), continuous fluidize bed and pulsed bed are various types of technique by which the contact between adsorbate and adsorbent is mainly occurred in the adsorption system. Fixed bed column is more preferable and industrially feasible for separating various contaminations from both synthetic and real waste water (Patel, 2019). The performance of fixed-bed column is studied by breakthrough curves, where the ratio of the effluent concentration to the influent concentration (C_t/C_o) against the flow time (t) (Lim and Aris, 2014). For the breakthrough curve, there are two important points which are breakthrough point and ineffective point. Breakthrough can be known as time taken for C_t to reach about 1-5% of C_0 (Geankoplis, 2003). Figure 2.2 and 2.3 below shows the breakthrough curve example from the past studies. From the figure, it is observed

that time of breakthrough and time of exhaustion increase with the increasing of bed depth (Biswas and Mishra, 2015).

From the previous studies, there are few factors that contribute in fixed-bed column studies which most of it is the effect of bed height and effect of flow rate that have been determined in the breakthrough curve. The factors contributions are shown in figures below.

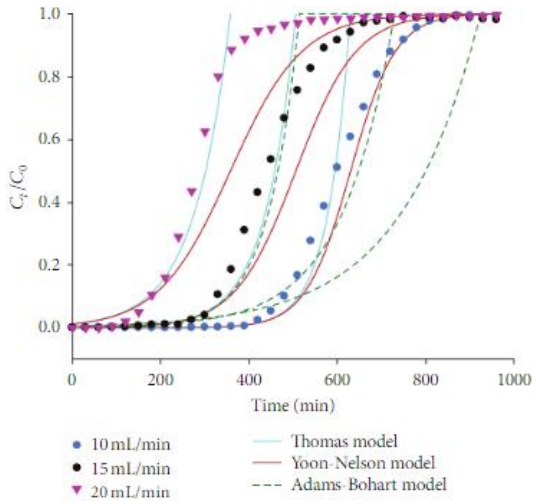

Figure 2.2: Effect of flow rate on breakthrough curve concentration 20mg/L; bed depth 5cm; pH 5.2 (Biswas and Mishra, 2015)

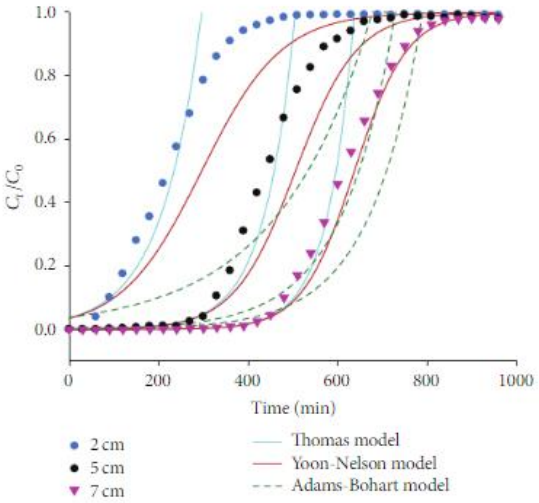

Figure 2.3: Effect of bed depth on breakthrough curve (flow rates 15mL/min; concentration 20 mg/L; pH 5.2 (Biswas and Mishra, 2015)

2.8.1 Effect of Flow Rate

Flow rate is an important aspect in either the adsorption study because it can give an impact towards the thickness of the boundary layer surrounding the particles and the external mass transfer coefficient. The removal of the pollutants will decrease if the flow rate is higher due to the decrease of film mass resistance at the surface adsorbent which causes shorter residence time and lack of contact time to the adsorbent. At higher flow rate, the sharper the breakthrough curves, the higher the breakthrough and exhausting time (Lim and Aris, 2014).

2.8.2 Effect of Bed Height

Bed height also an important operating factors which it can affecting the pollutant removal rates. The breakthrough and exhausting time will increased as the bed time increase which provides more binding sites for the pollutants to be adsorbed on the adsorbent and lead the greater mass transfer zone for the process (Patel and Vashi, 2015).