REDUCTION OF *ESCHERICHIA COLI* IN ABLUTION, LAKE AND RIVER WATER USING PORCELANITE

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REDUCTION OF *ESCHERICHIA COLI* IN ABLUTION, LAKE AND RIVER WATER USING PORCELANITE

By

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DEDICATION

To..

My mother and dearly loved family...

My husband and wonderful kids…

My supervisors for their efforts…

I dedicate this work.

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First of all, thanks to ALLAH for giving me the strength and fortitude to undertake this research work. I would like to specially acknowledge to my supervisor, Professor Dr. Norli Ismail for her invaluable suggestions, support, constructive criticisms and beneficial comments as well as fruitful discussion that have remarkably influenced this research work. Special thanks with appreciated to my Co-Supervisors, Associate Professor Dr.Abbas and Dr.Japareng for their help, guide and support during study. I would also like to extend profound gratitude to my family for their unremitting support, encouragement and boundless patience with me throughout the years of the research, especially my mother, which bore the separation, as well as my husband and my kids, who bore the alienation and distance from the family without complaints and was supportive of me.

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Suhair Shatti Salih

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
R^2	Coefficient of determination
APHA	American Public Health Association
BOD5	Five-day biochemical oxygen demand
COD	Chemical oxygen demand
NTU	Nephelometric Turbidity Unit
TSS	Total Suspended Solids
E. coli	*Escherichia coli*
rpm	Revolutions per minute
CFU_s	Colony Forming Units

PENGURANGAN *ESCHERICHIA COLI* DALAM AIR WUDUK, AIR TASIK DAN AIR SUNGAI MENGGUNAKAN PORSELANITE

ABSTRAK

Kajian ini bertujuan untuk menyiasat penggunaan porselanit dan klorin (natrium hipoklorit) untuk pengurangan *E.coli* dalam sampel air yang diperolehi dari Sungai Pinang, Tasik Harapan, dan air wuduk dari Masjid Khalid, Universiti Sains Malaysia, Pulau Pinang. Kesan pH, dos porselanit, saiz butiran dan suhu telah dinilai. Eksperimen ini telah dijalankan ke atas pelbagai jenis dos (40, 50, 60, 70, 80, dan 90 mg/ L), saiz butiran porselanit (0.09, 0.1, 0.2, 0.3, 0.4, dan 0.5 mm), pH (5, 6, 7, 8, dan 9) dan suhu (10, 20, 30, dan 40℃). Proses makmal yang terlibat ialah pengenceran sampel (1:10 dan 1:100) dan inokulasi pada agar MacConkey dan pada petri agar Eosin Metilena Biru. Selepas pengeraman, koloni-koloni telah dihitung menggunakan pengira koloni. Keputusan yang diperolehi daripada 108-larian (dengan tiga replikasi) reka bentuk faktorial telah dianalisis. Analisis varians (ANOVA) mendedahkan bahawa model disebut melengkapi secukupnya data ujikaji bagi semua tindak balas. Hal ini boleh dilihat bahawa kesan linear bagi pH, dos porselanit, saiz butiran dan suhu bagi pengurangan *E.coli* adalah penting. Berdasarkan semua eksperimen yang telah dijalankan, pH 5, suhu 40℃, 90 mg/ L dos porselanit dan 0.09 mm saiz butiran telah dipilih sebagai parameter terbaik bagi pengurangan *E.coli.* Gabungan faktor-faktor ini (dos porselanit, pH, suhu dan saiz butiran) mengakibatkan 98.6% pengurangan *E.coli* untuk air wuduk, 96.3% dan 89.6% masing-masing bagi air sungai dan air tasik. Mikroskop Imbasan Elektron (SEM) Mikrograf menggambarkan sifat poros permukaan

porselanit dan lekatan antara *E.coli* dan permukaan porselanit. Pelbagai dos natrium hipoklorit, pH, kepekatan dan suhu telah diperiksa pada sampel. Keadaan rawatan terbaik untuk penggunaan natrium hipoklorit untuk pembasmian *E.coli* adalah 0.14 ml/ L dos, pH 5, kepekatan 1%, dan suhu 20℃. Pengelompokan dos, pH, suhu dan kepekatan telah menghasilkan 99.6% kecekapan pembasmian untuk air wuduk, dan 96.3% dan 90.3% masing-masing untuk air sungai dan air tasik. Penggunaan porselanit dalam COD, BOD_5, TSS dan pengurangan kekeruhan sampel air yang dipilih (Sungai Pinang, Tasik Harapan dan air wuduk) telah juga diuji. Hasil kajian menunjukkan pengurangan yang lebih tinggi telah dicapai bagi COD dan BOD_5 dengan 90 mg/ L dos porselanit. Pengurangan COD dan BOD_5 dicatatkan sehingga 63.67% dan 62.33% untuk air wuduk, 59.33% dan 58% untuk air Sungai Pinang, manakala 57% dan 55% untuk air Tasik Harapan. Manakala bagi TSS dan pengurangan kekeruhan, dos porselanit yang berkesan adalah 50 mg/ L pada pH 5, suhu 40 dan saiz butiran 0.09 mm. Keputusan menunjukkan bahawa 92% TSS dan 91% kekeruhan telah dikeluarkan. Hasil kajian ini menyimpulkan bahawa porselanit dan natrium hipoklorit dapat mengurangkan *E.coli* dengan kadar tumpu, dan dipengaruhi oleh TSS dan kekeruhan air. Di samping itu, porselanit boleh mengurangkan tahap COD, BOD_5, TSS dan kekeruhan.

REDUCTION OF *ESCHERICHIA COLI* IN ABLUTION, LAKE AND RIVER WATER USING PORCELANITE

ABSTRACT

This study aimed to investigate the use of porcelanite and chlorine (sodium hypochlorite) for the reduction *E.coli* in water samples obtained from Pinang River, *Harapan* Lake, and ablution water from Khalid Mosque, Universiti Sains Malaysia, Pulau Pinang. The effects of pH, dosage of porcelanite, grain size and temperature were evaluated. The experiments were performed over a wide range of dosage (40, 50, 60, 70, 80, and 90 mg/L), porcelanite grain size (0.09, 0.1, 0.2, 0.3, 0.4, and 0.5 mm), pH (5, 6, 7, 8, and 9) and temperature (10, 20, 30, and 40℃). The laboratory process involved in this study was preparation of serial dilutions of the sample (1:10 and 1:100) and cultivating these dilutions on MacConkey agar and Eosin Methylene Blue agar plate. After incubation, the colonies were counted using colony counter. The results obtained from 108-runs (with three replicates) factorial design were analyzed. The analysis of variance (ANOVA) revealed that the mentioned model adequately fitted the experimental data for all responses. It could be seen that linear effect for pH, dosage porcelanite, grain size and temperature for reduction of *E.coli* were significant. Based on all the experiments performed, pH of 5, temperature of 40 ℃, porcelanite dosage of 90 mg/L and grain size of 0.09 mm were selected as the best parameters for *E.coli* reduction. The combination of these factors (dosage of porcelanite, pH, temperature and grain size) resulted in 98.6% *E.coli* reduction for ablution water, 96.3% and 89.6% for river water and lake water, respectively. The Scanning Electron Microscope (SEM) micrographs illustrated the porous nature of the porcelanite surface and adhesion

between *E.coli* and surface of porcelanite. Various dosages of sodium hypochlorite, pH, concentration and temperature were examined on the sample. The best treatment conditions for the use of sodium hypochlorite for *E.coli* eradication were 0.14 ml/L, pH 5, 1% concentration, and temperature of 20^{o}C. The grouping of dosage, pH, temperature and concentration resulted in 99.6% eradication efficiency for ablution water, and 96.3% and 90.3% river water and lake water, respectively. Applicability of porcelanite in COD, BOD_5, TSS and turbidity reduction of selected water samples (Pinang River, Harapan Lake and ablution water) were also tested. Results revealed higher COD and BOD_5 reduction were achieved by porcelanite dosage of 90 mg/L. COD and BOD_5 reductions were recorded up to 63.67% and 62.33% for ablution water, 59.33% and 58% for Pinang River water, whereas 57% and 55% for Lake Harapan water. While for TSS and turbidity reduction, the effective dosage porcelanite was 50 mg/L at pH 5, temperature of 40 ℃ and grain size 0.09 mm. The results showed that 92% of TSS and 91% of turbidity were removed. The results of this study conclude that porcelanite and sodium hypochlorite able to reduce *E.coli* with a convergent rate, and influenced by TSS and turbidity of water. In addition, the porcelanite can decrease COD, BOD_5, TSS and turbidity level.

CHAPTER ONE

INTRODUCTION

1.1 Surface water contamination

There has been a universal interest about fecal contamination of natural water bodies and its potential impact on human health. Several studies on Best Management Practices (BMPs) have been conducted to reduce untreated human and domestic animal waste discharge, however, our limited understanding of bacteria dynamics within a watershed remains imperfect (Embrey, 2001).

Rapid industrial and agricultural developments during the past few decades have changed the sediment and water quality of the natural lakes around the world. Metallic elements, acidification, pesticides and oil are the key areas of concern for the researchers for evaluating impact assessment in the ecosystem (Xu, 2005).

Surface water contaminants generally comprise physical, chemical, and biological impurities, which include turbidity, color, algae, floating debris, bacteria, microorganisms, and the constituents of ground water (Gillett, 1998). Although appearance taste and odour are practical determinants of the quality of drinking water, suitability in terms of public use is established based on the microbiological, physical, chemical, and radiological characteristics. The most significant characteristic needed to be evaluated is the microbiological quality although several chemical contaminants (both organic and inorganic) found in water may also cause health problems. Therefore, water pollution studies demands detailed analysis of all factors and variables that affect water purity (Vigneswaran and Visvanathan, 1995).

Fecal contamination is one of the major environmental problems facing not only the industrial countries of Europe and North America, but also countries that are still on the verge of industrial development, like Malaysia. Its compositional *E. coli* is a gram-negative, non-sporulating bacterium. The presence of fecal coli in aquatic environments may indicate that the water has been contaminated with the feces of humans or direct discharge of waste from mammals and birds, from agricultural and storm runoff and from human sewage. However, their presence may also be the due to plant material, pulp or paper mill effluent (Doyle and Marilyn, 2006). In 1914, the U.S. Public Health Service (USPHS) created an *E. coli* form index using the density of total coli form bacteria as the indicator of ambient water quality in the United States (Maier et al., 2000). Also, occurrence of *E. coli* in water was used as a marker to examine the possible incidence of other more dangerous microbes, such as Cryptosporidium, Giardia, Shigella, and norovirus. The use of untreated or inadequately treated water containing fecal contamination for drinking may result in illness (Hernandez-Delgado et al., 1991).

1.2 Water matter content

American Public Health Association (APHA, 1989) defines turbidity as the optical property of the water sample that causes light to be scattered and absorbed rather than being transmitted in straight lines. The sources of turbidity was construction works involving the replacement of top soils with impervious surfaces which may disturb existing ground cover and expose the surfaces causing an increase in the amount of sediments discharge especially during rain (Low et al., 2011). Changes in turbidity can have direct and indirect impact on aquatic life. At extremely high levels, turbidity can directly affect fish and invertebrates growth and survival (Meager and Utne, 2008).

Turbidity is affected by the interaction between light and suspended particles in water. Suspended solids have the ability to hinder light transmittance in water. Light scattering intensifies with increase in TSS concentration (Sadar, 1998). Therefore, turbidity could provide a good estimate of the concentration of TSS in a water sample even though turbidity is not a direct measure of suspended particles in water (Gallegos et al., 2005). Earlier studies consistently showed a strong correlation between TSS and turbidity (Gippel, 1988) and the relationship between TSS, turbidity and *E. coli*. The increase or decrease in fecal coli levels is consistent with the deposition of bacteria bound to suspended sediment. Also, increase in TSS concentrations leads to subsequent increase in turbidity levels (Howell et al., 1996).

E. coli is a type of bacteria usually originates in the intestines of animals and humans, also found in unpasteurized milk and turkey, chicken, beef, sandwich meats, raw vegetables, cheese and contaminated water (Hernandez-Delgado et al., 1991).

Chemical Oxygen Demand (COD) is a measure of oxygen matter contained in water or waste water that can be oxidized by a strong oxidant mostly potassium dichromate ($K_2Cr_2O_7$) (Sawyer et al., 2000). The Biochemical Oxygen Demand (BOD_5) is carried out to examine the effect of bacteria and organic materials found in dirty water animal and plant life when released into a stream or lake. The abundance of bacteria and organic materials requires oxygen in order to breakdown these molecules (Barnes et al., 1998; Holmbeck and Rasmussen, 1997).

1.3 Significance of water treatment

It is important to keep water uncontaminated so as to lessen environmental and health risks. Clean water is crucial to aquatic life in order to sustain the fishing industry and sport fishing enthusiasm for present and future generations (ANZECC, 1992; Pearce et al., 1989). Wildlife territory, rivers and ocean waters depend on shoreline, beaches, and marshes. They are critical habitats for hundreds of species of fish and other aquatic life (Johnstone et al., 2009).

Water is a vast playground for recreational activities. The beautiful scenic surroundings of waters attract people to live by beaches and other exotic aquatic dwellings. Visitors and tourists are drawn to water activities such as swimming, fishing, boating, and picnicking. Most importantly, water is a media for diseases if not properly cleaned. Therefore, harmful bacteria have to be removed to prevent epidemics (Cowan and Talaro, 2006).

1.4 Water treatment

1.4.1 Porcelanite rock

Porcelanite is a name given to the reddish siltstone rock that caps many ridges and buttes in the Powder River Basin which resembles the coal-burning waste called clinker or volcanic scoria. Based on further study by (Dublin et al., 2005) at North Dakota's Clinker a rock, semi vitrified clay or shale, somewhat resembles jasper which is composed of mullet and other high-temperature silicate and oxide minerals. These are formed due to combustion metamorphism (e.g., burning coal seams and dumps, mine fires) (Hoganson and Murphy, 2003).

Researchers did not widely know about Ninivite and it was discovered in 1987 during detailed geological mapping of some areas in Mosul (Iraq). Ninivite was then defined as a new form of Porecelanite (Al- Naqib and Al-Dabbagh, 1990).

Globally, many researchers have focused on this subject in order to find innovative and cost effective water treatment methods. To eradicate or lessen the amount of pollutants in surface water, numerous water treatment methods have been adopted. Biological processes are the most cost effective, but they are not sufficiently effective if used solitarily without pre-treatment methods. Physicochemical methods such as adsorption and coagulation have also been used to enhance biodegradability (BOD_5/COD ratio) and for the treatment of *E. coli* (Hunt and Marinas, 1999).

Adsorption is effective in most natural physical, biological, and chemical systems, and is extensively applied in the form of activated carbon and, synthetic resins for industrial waste and wastewater purification systems (Kopecký et al., 1996). There are several adsorbents (alumina and silica gel) in use, though activated carbon remains most accepted and is used widely in water treatment to remove bacteria and decrease turbidity (George et al., 2013). Porcelanite rocks are great adsorbents because they contain high percentage of silicon. A number of researchers had carried out a study on adsorption of metal ions by using porcelanite rocks as adsorbents (Jameel et al., 2010).

Coagulation is a process where compounds such as porcelanite powders are added to contaminated water in order to destabilize colloidal materials and cause the aggregation of small particles into larger more easily removed flocs (Stephenson and

Duff, 1996). The separation of suspended solids from river water has been the subject of many studies over the years.

Porcelanite as filter is superior in removal of turbidity and as the porosity of ninivite increases, the spaces among grains also increase (Al- Rawi, 1987). Further the granular media of the porcelanite filter could strain more small particles such as bacteria (Crittenden et al., 2005).

High turbidity water (450 NTU) can be removed using silica as coagulant aid with 60% of alum, where values obtained are final turbidity of 4.56 NTU with removal percentage of 98.98%. This value of turbidity is consistent with Iraqi specification for potable water (Suad et al., 1990). Turbidity water can be removed by 92% using porcelanite with coagulant dosage of 25 mg/L (Arkan, 2012). Other study by Tang et al., 2006 evaluated the performance of crumb rubber as filtering material for ballast water treatment. It was found that crumb rubber is an excellent filter media for downward granular media filters in comparison to traditional granular media filters, a substantial reduction in turbidity was achieved, no clear relationship between filter depth and turbidity removal efficiency was found, higher filtration rate resulted in lower turbidity removal efficiency. Additional study by Juosh et al., 2006 used palm shell as single and dual media filter. Palm shell is one of the industrial wastes that are abundantly available. Result suggests that all the filters are capable of producing water with acceptable turbidity of 1.0 NTU.

1.5 Water chlorination

Water chlorination is the disinfection process of adding chlorine to water in order to make it healthy for human consumption as drinking water. Water treated with chlorine is effective in preventing the spread of waterborne diseases. Moreover, chlorine is a highly efficient disinfectant for eradicating disease-causing pathogens such as bacteria, viruses and protozoan that normally grow in water supply reservoirs, on the walls of water wells and in storage tanks. As a strong oxidizing agent, chlorine kills via the oxidation of organic molecules (Calderon, 2000). According to Environmental Protection Agency (U.S. EPA, 1999) all form of chlorine are toxic, even at low concentration thus requiring increased safety system, also low doses of chlorine it is not effective against some parasitic and protozoa. The chlorine can cause a worsening in coagulation and filtration of dissolved organic substances in addition chlorine (sodium hypochlorite) degrades over time and with exposure to light (Masschelein, 1992).

1.6 Problem statement

The quality of surface water (lake, river) is unpredictable, because the water continually moves and pollutants can be introduced at any time. In other words, an area of lake or stream that is fine one day may be contaminated the next. Biological contaminants can come from sewers and failed septic systems, boat toilets, animals, and other sources. While physical contaminants of surface water which include turbidity, color, algae, floating debris (Gillett, 1998). Treatment of water has two steps, filtration and disinfection. Both steps are necessary to remove or kill all bacteria, viruses, and parasites and make the water safe to drink. However, the treatment approaches are often expensive, time consuming and cause secondary pollution problems. Therefore, an effective approach in surface water treatment technology using porcelanite should be developed in the removal of turbidity, TSS and *E. coli* in surface water.

Although there have been many studies on the effectiveness of surface water treatment using porcelanite, the relationship of factors i.e, temperature, pH, grain size and dosage of porcelanite have not been widely researched. Therefore, in this research these factors are considered. Another factor that is not widely reported is the mechanism of removal. Although reports on percentage of COD, BOD_5 reduction and TSS removal are extensive, publications on possible mechanisms of *E. coli* removal are almost nonexistent. The results of the study could provide a scientific and engineering basis to design a new reactor system in order to gain an understanding of the tools for predicting design parameters in treating turbidity, TSS and *E. coli* in surface water and ablution water. There are some concerns regarding chlorine usage that may impact its uses such as: Chlorine reacts with many naturally occurring organic and inorganic compounds in water to produce undesirable DBPs (Disinfection by- Products), also the turbidity effects on the chlorine activity for *E. coli* (Kelly, 2004). High chlorine doses can cause taste and odor problems (Lindsay and Lorene, 2004), (Baikun and Bruce, 2004). So the disinfection of water by sodium hypochlorite needs to use the processors of initial sterilization before its application.

1.7 Scope of study

Based on the aforementioned problems in Section 1.6, this study intends to focus on efforts that will bring the required solution by utilizing porcelanite to reduce *E. coli* ,turbidity, TSS ,COD and BOD_5 in ablution, river and lake water.

1.8 Research objectives

The aim of the study is to investigate the potential of porcelanite to reduce *E. coli,* COD and BOD_5 in the surface water (ablution, river and lake water). Therefore the study was carried out as follows:

1- To determine the effective dosage of porcelanite for *E. coli* reduction in selected water samples

2- To determine the reduction efficiency of BOD_5, COD, TSS and turbidity using various grain size and dosage of porcelanite.

3- To compare between porcelanite and sodium hypochlorite for *E. coli* reduction in selected water samples.

1.9 Thesis outline

Chapter one provides a concise introduction into surface water, water treatment and objectives of this study. Chapter two presents a wider insight into surface water treatment using porcelanite and sodium hypochlorite. It also includes a review of previous studies carried out in the related fields. Chapter three entails the methodology used in this study and specific condition to do laboratory analyses. Chapter four comprises results of the experiments that had been carried out along with discussions. Chapter five is the conclusion of this study and also includes recommendations for future studies in this area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Water is known as the basic material found most abundant in the protoplasm which is the backbone of life. It is importance in human life and for the rest of living organisms. The evolution of human societies and the progress of agriculture, industry and increase in the prosperity and eradication of pests and diseases have contributed to increase in population numbers may cause pollution of natural water (AMAP, 2002).

Water has the ability to purify itself, which attaches its impurities and environmental factors which help the impurities in its ability to afford the source and treatment (Omer and Muthanna, 2000) during a process well-known as self purification, These methods be able to give notice to dilution of polluted water with flood of surface and groundwater or by chemical processes such as sedimentation Ongley (1991) and Ifabiyi (2008). While increasing in volumes and concentrations of contamination in water has become difficult for the water purification itself (Rupert et al., 1996). Note that the different uses incurred by human societies like progress of agriculture, industry have made the amount of pollutants rise into the rivers (Jusi, 1989).

The fresh water on the planet constitutes only 0.003% and includes lakes, rivers, groundwater and snow, Nitti and Gianfranco (2011). These small percentages of fresh water play a fundamental role in human life because it is the most appropriate source of water for household needs. In addition, it provides as a suitability system for the disposal of waste and its associated water plants (Gleick, 2012). Water pollution may occur due to the fundamental problems of inappropriate human actions such as discharge of agricultural, industrial pollutants and domestic ones to the sources of natural water (Joseph, 1982).

2.2 Chemical and physical properties of water

Physical and chemical properties of water play a direct role in the distribution of living and behavior of aquatic organisms. Temperature is among the most important of these properties and related to the contamination of water. Therefore, we note that some research and environmental studies put this aspect in the first place because of seasonal variations and this may lead to sudden breach and clearing and distribution of neighborhoods and this may be main factor of the contaminated environment (Sabri et al., 1993). In addition, it will directly or indirectly affects on the physical and chemical characteristics of water (Weatherley and Gill, 1987; APHA, 1995; Mislevy and Riconscente, 2005).

pH is one of the main factors affecting the neighborhoods inside water especially as the microstructure of acidic or basic conditions may lead to decomposition of some compounds cells such as germ crash or some enzymes (Atlas and Bartha, 1986). In study by Frais et al. (2001) and Lantagne (2008), sodium hypochlorite has been used as disinfectant. The authors found that disinfection was effected significantly by pH and temperature. While the other study by Onundi et al. (2010) found adsorption of porcelanite was affected by pH. Meanwhile in another study done by Ernest and Calvert

(1969), Isaacs et al. (1983) had found increasing in temperature led to increase in the effective grain size of porcelanite.

The turbidity is a factor to contest directly or indirectly on biology and other environmental factors and it naturally affect water transparent to light rays passing through it (Jeff, 2001). Alternatively this feature change the appearance of dark material or alluvial clay or other materials and in infinitesimal manner remain stuck in the water and there is an inverse relationship between the turbidity and the depth of light region, which occur as per the process of photosynthesis. There is a direct relationship between Turbidity and microbiology (Omer and muthanna, 2000).

Total suspended solids (TSS) are solid organic and inorganic materials that suspend in water. Suspended solids are the materials that turn the water cloudy, after it has been stirred. The materials include natural, industrial, and commercial wastes. Scraps and remnants of food solids as well as fat, oil, and grease from restaurant or commercial kitchen waste contribute a lot to TSS counts (Atul, 2007; Bent et al., 2001).

Suspended solids absorb heat from sunlight, which increases water temperature and decreases oxygen levels (cooler water holds more oxygen than warmer water) (Ginting and Mamo, 2006). Since aquatic plants receive less light, photosynthesis decreases and less oxygen is produced. The occurrence of warmer water, less light and less oxygen makes it impossible to sustain aquatic life.

Suspended solids also affect marine life in several ways, such as clogging fish gills, reducing growth rates, decreasing disease immunity, and hampering egg and larval development (Javed et al., 2010). According to Environmental Protection Agency (U.S. EPA,1999) and the World Health Organization (WHO, 2003) chloride has a great ability to sterilize water, but what worries the experts is the material resulting from the interaction of chlorine with organic substances its effects on public health.

According to study by Estrela et al. (2002), sodium hypochlorite solution when contact with organic tissue decreases the efficacy of chlorine as disinfection. In study by Amal et al. (2009), the author found that optimum doses of porcelanite are used as coagulant aids for reduction of the turbidity and TSS is 18 (mg/L), whilst Arkan (2012) has found of turbidity water could be removed up to 92 % by using porcelanite as coagulant with a dosage of 25 mg/L.

The presence of sufficient amount of oxygen in the water helps the transformation of some compounds containing other elements to the chemical groups (roots) and then to the molten salts do not sharply affect the specification of the basic water (Yusuf et al., 2012). Any deficiency in the oxygen concentration is harmful to aquatic life and a guide to organic pollution (EPA, 1986). Therefore, oxygen is used to estimate the amount of organic waste in the form of water by measuring the amount of oxygen necessary for the bacteria to oxidize waste aerobically to binary oxide carbon and water for a certain period, and the symbol of this measurement are indicated by BOD_5, while for determined the organic pollutants found in the lakes and rivers are indicated by COD (Barnes et al., 1998).

An additional study by Mohammed et al. (2012), the reduction of BOD_5 and COD by multimedia biological filter (sand, granular activated carbon and crashed porcelanite) was 89.9% for COD, 88.9% for BOD_5, while both *E. coli* and total coliform reaches 94% and 91% respectively. Another study done by (Ansary, 1998; Al-Saqqar and AL-bayaty, 2008; Dheyaa ,2009) had suggested porcelanite as good filtering media to reduce turbidity and TSS.

2.3 Water pollution

Water pollution is the most important problems, which is reflected in harm to human health and environmental regulations and the development of civilization (Al-Saadi et al., 1994; Renwick, 1999).

The enormous development in the development of agricultural fields and animal communities and the establishment of industrial and population on water resources has increased the water pollution problems and this has become a health risk to consumers of those waters (Carey, 1992). There is no control on the extent of polluted water generations and are greatly dependent on treatment operation. In addition, the ability of the organic waste to be biodegrade is one of the most prominent water problems as they affect the amount of dissolved oxygen negatively.

In the last few decades, acquired water has added on importance because of the cost and increasing demand, and coupled with its increasing pollution, untreated dirty water from rural communities and that from civil one are the main factors that lead to increase in the eutrophication of rivers and lakes (Obire et al., 2003; Manja et al., 1982).

In relation to the pollution sources of Sungai Pinang Basin water attributed to anthropogenic activities such as domestic sewage, agricultural and industrial wastes (DID, 2000; Koh, 2004). While the main cause of pollution in lake Harapan is the poor quality of storm water which flows into lake through Sungai Gambir. The storm water manages to flow through the control gate at the inlet when the level of water increased.

This situation has contributed to the loss of ecological functions and destruction of ecosystem in the lake (Zorkeflee et al., 2011).

The regular use of water by Muslims to perform ablution plays a role in water contamination. Generally, ablution consumes an average of 2 to 3 liters of purified tap water. Considering the billions of Muslim population worldwide, billions of liters of water is expected to be consumed during ablution on a daily basis (Mohd, 2011). Presently, water used for ablution enters the urban sewage system with black water (water of toilets or kitchen sinks or dishwashers) (Prathapar et al., 2006). In addition, ablution waters discharged from mosques can be considered as a source of grey water. Ablution water is different from household grey water because it does not contain food or chemical products (Prathapar et al., 2004). This grey water may contain suspended solids, biological oxygen demand (BOD_5), pH, dirt, turbidity, and some fecal coli form contaminants. Sometimes, this water contains chemical pollutants, such as nutrients and sodium from chemical products, such as soap for washing. Also, ablution water contained soil particles and some bacteria (*E. coli*) from feet and hands of worshippers respectively (Mohammed et al., 1991).

2.4 *Escherichia coli*

E. coli is a Gram-negative, rod-shaped bacterium commonly found in the lower intestine of warm-blooded organisms Vogt and Dippold (2005). At temperatures of up to 49°C (120.2°F), *E. coli* has ability to growth, but optimal growth occurs at 37°C (98.6°F) and sometimes laboratory strains can multiply and growth under aerobic or anaerobic growth conditions (Fotadar et al., 2005).

E. coli exists naturally and easily to obtain from a few sources which include bowels of humans and animals and also warm-blooded such as birds Shibata and Rose (2006). Physiologically, *E. coli* is versatile and well-adapted to its characteristic habitats. In the laboratory it can grow in media with glucose as the solitary organic constituent. The bacterium can grow in both aerobic and anaerobic conditions. It grows by means of fermentation under anaerobic conditions to produce distinctive mixed acids and gas as end products. In addition, it can grow by anaerobic respiration because of its ability to utilize NO_2, NO_3. This characteristic feature makes *E. coli* adapt to intestinal (anaerobic) and extra-intestinal (aerobic or anaerobic) habitats (Neidhardt et al., 1990) and (Jim, 2009).

E. coli can fluctuate the pore diameter of its outer membrane in response to disparity in temperature and osmolarity in order to accommodate larger molecules (nutrients) or to keep out inhibitory substances like bile salts, using its intricate mechanism for regulation of metabolism, the bacterium can assess the chemical content of its environment so as to produce enzymes required to synthesize these compounds (Thanassi et al., 1997). It does not profligately produce enzymes for the breakdown of carbon sources except they are present, and it does not produce enzymes for synthesis of metabolites if exist as nutrients or growth features in the environment (Kenneth, 2009).

It has indicated that contaminated water causes many diseases, especially diarrheal diseases (Bockemuhl, 1985). Also typhoid, polio, viral hepatitis, respiratory diseases and disease discloses amoebae; water is a mode of transport for many of the causes of these diseases. Further related disease caused infrequently are personal hygiene (water scarcity) related, bacillary diarrhea, fever counterpart, worm pinworm, disease discloses amoebae, scabies, poisoning, rot the skin, ulcers, lice and typhus, trachoma and conjunctivitis, those diseases related to inappropriate sanitation are worm noodles, worms and ascariasis and disease lattice tail and hookworm (Graun, 1989; Elmun et al., 1999; Donald, 2001).

2.5 Water disinfection

2.5.1 Chlorine

Chlorine is not only known as disinfectant agent that effectively kills bacteria but also because it being the most versatile chemical used in water and wastewater disinfection with regards to easy in handling and cost effectiveness. Due to that several studies have focused on sewage disinfection using chlorine. To be further elaborate on the favorable uses of chlorine, listed were some of the examples on the multi-purposes use of it such as in disinfection control of microorganisms, removal of ammonia, control of taste and smell, colour reduction, destruction of organic matter, hydrogen sulfide oxidation, iron and manganese oxidation. In order to kill bacteria and viruses associated with the water dam surface, chlorine was used for a long time in the sterilization of drinking water due to its effectiveness in doing so. As such, in order to eradicate these critical epidemic diseases there are no doubt that the use of chlorine has had a significant health benefits to society and as well as various intestinal diseases caused by bacterial contamination of drinking water (Gordon et al., 1987; Gordon, 2001).

According to health reports made by U.S. Environmental Protection Agency (EPA, 1990) among 44% of consumers who used water container that could not stand on the chlorine reaction, there is evidence on the relationship of colon cancer, bladder and rectum on consumption of chlorinated water that was stored in inappropriate container.

This brought a significant exposure for the consumers today on the exposure of chlorine while taking shower versus drinking the same chlorinated water having a higher potential risk of THMs (Trihalomethanes) getting into the digestive system. There was a link to bladder cancer as reported by Wones and Glueck (1986) due to taking hot shower where the hot water will open up the pores of the skin and thus takes the chlorine and other pollutants on its way to the body through the skin. Further study indicated that inhalation of chlorine vapor during the bathing increases the problems of asthma, allergies and sinus exposure on short term for these conditions and may cause eyesore, cough, sputum, Admen nose, and chest pain. Meanwhile on a larger scale it may cause accumulation of fluid in the lungs, pneumonia and bronchitis, and shortness of breath (Lindstrom et al., 1997).

Keeping amount of chlorine constant, a professor of water chemistry at the University of Pittsburgh (USA) explained that exposure to chemicals vaporized during use of shower has the effect 100 times more to that of drinking the same water as the body absorbs the volatile chemical while taking shower bath (Barone, 2012).

The use of disinfectants in water treatment of bacteria has been regarded as a major research area. They involve the use of oxidizing agents to oxidize the cell membrane of microorganisms, which leads to loss of cell structure and death (Al-Kdasi et al., 2004). Other methods include the use of chlorine, which is introduced to water in the form of gas, hypochlorite (tablets, solutions, or powder), solid (calcium hypochlorite, available in powder or tablets, or as a liquid (sodium hypochlorite solutions, available in concentrations ranging from 5 to 15%), and other compounds (Kevin, 2008).

2.5.1.1 Sodium hypochlorite

Sodium hypochlorite is a chemical compound with the formula NaClO. Sodium hypochlorite solution, commonly known as bleach or liquid bleach, is often used as a disinfectant or a bleaching agent in the home to disinfect drains, toilets, and other surfaces. In more dilute form, it is used in swimming pools. It can be used in drinking water after further dilution (Weber et al., 1999).

Latest study by Bjerregaard (2014), concluded that sodium hypochlorite killed *E. coli* with percentage of (99.9%) after 1 min exposure at pH 7 while at pH 9 it killed 90% of *E. coli* after 5 min exposure. Another study by Zakaria et al. (2009) found that sodium hypochlorite has capability to kill *E. coli* with percentage of 98.38% at 2.5% concentration and temperature of 37℃.

2.5.1.2 Calcium hypochlorite

Calcium hypochlorite is a chemical compound with formula $Ca(ClO)_2$. It is extensively used for water treatment and as a bleaching agent. This chemical is regarded to be reasonably stable and has greater available chlorine compared to sodium hypochlorite (liquid bleach).

According to health reports made by U.S. Environmental Protection Agency (EPA, 1999), Calcium hypochlorite is also used particularly as a swimming pool additive with concentration 70%. Calcium hypochlorite is normally used in small applications because of its high cost. This unstable chemical could likely release chlorine gas when it comes in contact with water, (Kevin, 2008). The characteristics of hypochlorite as shown in Table 2.1.

Table 2.1 Characteristics of hypochlorite (Linton et al., 1987and Nahems, 2011).

Disinfectant Category	Hypochlorite
Sample Trade Name	Bleach
Mechanism of Action	Denatures proteins
Advantages	• Broad spectrum • Short contact time • Inexpensive
Disadvantages	• Inactivated by sunlight • Requires frequent application • Corrodes metals •Mucous membrane and tissue irritation
Precautions	Never mix with acids; toxic chlorine gas will be released
Bacteria	Effective
Viruses	Effective

2.6 Water treatment by porcelanite rock

Porcelanite as filter is superior in removal of turbidity, the porcelanite has high absorption and adsorption ability (Muath, 2008).These ability may be due to the chemical and physical composition of porcelanite (Jassim and AL-Naqib, 1989). It was found that optimum dose of porcelanite for coagulation to remove turbidity is 18 mg/L (Amal et al., 2009). Recent studies have shown that porcelanite as filter is a promising and effective method for removing the turbidity and bacteria compared to other filters. It may be due to the granular shapes of the porcelanite filter that could retain more small particles such as bacteria (Al-Najjar, 2000). Al-Najjar (2000) and Muna (2010) have used porcelanite as dual medium in the filters for turbidity reduction. Another study by (Amal et al., 2010), used porcelanite with grain size range from 0.04 - 0.08 mm for *E. coli* removal in wastewater, and the coefficient of regularity (uniformity coefficient is 3.18). The results of study shows porcelanite was more effective to remove *E.coli* bacteria with percentage removal almost 100% and the reduction of BOD_5 and COD was 46% and 60% respectively.

2.6.1 Adsorption and Absorption

Adsorption is a process whereby substances are attracted and adhere to the surface of a solid (sorbent) by chemical bonds and /or physical forces. This process provides a viable alternative for the treatment of contaminated waters, particularly if the sorbent is cheap and does not demand supplementary pre-treatment steps before its application (Dabrowski, 2001).

In study by Al-Naqib and Al- Dabbagh (1990), comprehensive reviews have been carried out on the technical feasibility of various inexpensive adsorbents for bacteria and turbidity removal from contaminated water. For example (Jassim et al., 2010; Jameel et al., 2010) discovered a silica-rich rock in northern Iraq referred to as porcelanite. Porcelanite is characterized by high adsorption ability with a very high surface area that possibly exceeds 800 g/m^2 and they contain high percentage of silicon (Jassim and Jeremy, 2001; Uday, 2009).

Absorption is a process in which atoms, molecules, or ions enter some bulk phase –gas, liquid, or solid material. This process differs from adsorption, given that molecules undergoing absorption are taken up by the volumes, adhering to the surface (McMurry, 2003).

Porcelanite is characterized by high absorption ability because of large volume of pores and this led to increase the porosity values and the permeability of porcelanite (Majid et al., 2014). In study by Branger et al. (2007), the absorption of rock to *E. coli* at different stages: reversible and irreversible adhesion, the reversible (Van Der Waals forces) while irreversible adhesion occurs during cellular production of exopolymers that attach the *E. coli* to the surface of rock. Meanwhile research by Boulangé-Petermann et al. (1993) and Rubio (2002) stated the adhesion of *E. coli* on the surface of porcelanite can be significantly influenced by the chemical constituents of porcelanite ($p<0.05$). The absorption of bacteria to rock is maintained by the composition of both rock and bacteria structure (Nola et al., 2010).

Porcelanite is characterized by high water absorption rate (93.4-104.7%) which is demonstrated by its ability to absorb water from the bacteria leading to death within a short time (AL-Naqib and AL-Dabbagh, 1993). Another study by Ducman and Kopar (2007) concluded that Porcelanite is a light weight rock with density of 0.9-1.4 gm/cm^3, and considered as important industrial sedimentary rocks that composed of at least 50% of opal-CT (opal-cristobalite and tridymite).

The study by Ali and Budari (2011) was used granular bed filtration as a vigorous, simple and economical method to prevent the penetration of *E. coli* contaminations, by discovering an alternative filter media from local source namely the burnt oil palm shell (BOPS). The result indicated that dual media BOPS/sand were higher reduction and longer total service of time compare to anthracite/sand, whereas

BOPS/sand, 65.57% and anthracite/sand, 34.35% removal of *E. coli* by direct filtration process.

The rate of increase in the percent adsorbate removal has been found to be rapid which slowed down as the dose increased. This phenomenon can be explained, based on the fact that at lower porcelanite dose the adsorbate is more easily accessible and because of this, removal per unit weight of porcelanite is higher. With rise in porcelanite dose, there is less commensurate increase in adsorption, resulting from many sites remaining unsaturated during the adsorption (Jain et al., 2003). Test of SEM micrograph of the porcelanite rocks illustrated the porous nature of the porcelanite surface (Figure 2.1).

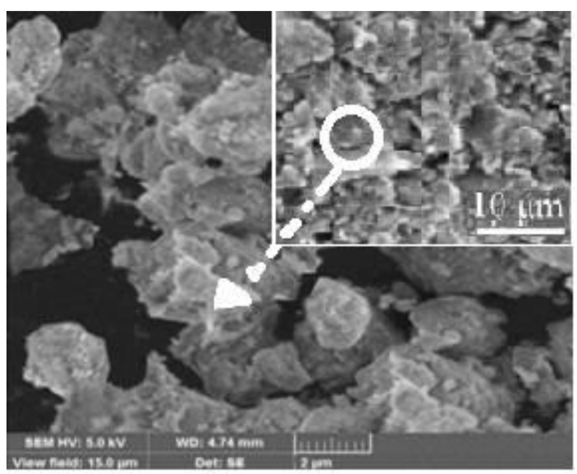

Figure 2.1 SEM micrograph of porcelanite.