ASSIMILATION OF COCONUT COIR PITH IN SLOW SAND FILTER (SSF's) TO IMPROVE WATER QUALITY IN WATER TREATMENT PLANT

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ABSTRACT

During this modern era, the majority of rural communities are still drinking superficial water that does not meet the required standard of quality, causing serious health problems. Filtration is one of the water treatment processes to ensure our drinking water is safe from physical contamination. Therefore, in the study was investigating the potential of slow sand filtration as a biofiltration by adding natural material (coconut coir pith) as a medium to filter raw water as to reduce turbidity, total suspended solid, heavy metal and presence of pathogen and feacal coliform and also to reduce chemical additive in the disinfection process which is harmful to the communities. The focus of this study is to investigate the effectiveness Slow Sand Filtration in treating raw water sample taken from JBA at water treatment plant at Semambu. Ten parameters were analyzed which include pH, turbidity, Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Coliform (TC), Escherichia Coli (E. Coli), Iron (Fe), Cooper (Cu) and Cadmium (Cd). The purpose of this study is to compare the effluent of water sample after treatment with conventional slow sand filtration and with integrated slow sand filtration which has additional coconut coir pith of granular activated carbon (GAC) layer in between of the filter bed. During this study, two pilot models of filter drum is built and the material will be used are wash sand (0.15mm – 0.3mm), gravel sand (2mm-5mm) and coconut coir pith as GAC (>5mm). From the result obtained, all the parameters were analyzed comply with Malaysian Drinking Water Standard 2009 guidelines. From the study, all result is most under range/limit in Malaysian Standard 2009. From the both model analysis, we can conclude that the water are safe be drink based on the small and acceptable limit of presence of heavy metal and the most effective type of filtration is with adding activated carbon in the medium of slow sand filtration tank.

ABSTRAK

Pada era moden ini, majoriti masyarakat luar bandar masih menggunakan air tidak dirawat yang tidak memenuhi piawaian kualiti yang diperlukan. Penapisan adalah salah satu pemprosesan air yang memastikan air minuman kita dapat dielakkan dari pencemaran. Oleh itu, kajian ini akan menyiasat potensi penapisan melalui lapisan pasir sebagai biofiltrasi dengan menambah bahan alam (sabut kelapa) sebagai bahan tambah untuk menapis air yang belum dirawat untuk mengurangkan kekeruhan, jumlah keseluruhan pepejal terampai, bahan kimia dan kehadiran patogen dan feacal coliform dan juga untuk mengurangkan bahan kimia tambahan dalam proses pembasmian kuman yang berbahaya bagi masyarakat. Tujuan kajian ini adalah untuk mengetahui keberkesanan *'Slow Sand Filtration'* dalam pemprosesan sampel air yang diambil dari JBA di logi air di Semambu. Sepuluh parameter dianalisis yang meliputi pH, kekeruhan, Total Suspended Solids (TSS), Biologi Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Coliform (TC), Escherichia Coli (E. Coli), Besi (Fe), Cooper (Cu) dan Kadmium (Cd). Tujuan dari penelitian ini adalah untuk membandingkan sampel air selepas rawatan dengan *'Slow Sand Filtration'* biasa dan dengan *'Slow Sand Filtration'* terintegrasi yang mengandungi tambahan*'Granular Activated Carbon'* (GAC) dari sabut kelapa yang diletakkan di antara lapisan pasir. Semasa kajian ini, dua model tong penapisan akan dibina dan bahan yang akan digunakan adalah pasir bersih (0.15mm - 0.3mm), pasir kerikil (2mm-5mm) dan GAC (> 5mm). Dari keputusan yang diperolehi, semua parameter dianalisis dan dibandingkan dengan piawaian kualiti air Malaysia 2009. Dari kajian ini, ke semua keputusan ekperimen adalah di bawah had piawaian kualiti air Malaysia 2009. Dari keputusan yang diperoleh, kita dapat menyimpulkan bahawa ke semua sampel air yg di analisis berada di bawah had limit piawaian kualiti air Malaysia 2009 dan penapisan yang berkasan adalah dengan bahan tambah *'Granular Activated Carbon'* sebagai medium dalam lapisan penapisan.

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BOD	-	Biological Oxygen Demand
COD	-	Chemical Oxygen Demand
E. Coli	-	Escherichia Coli
EPA	-	Environment Protection Agency
FKASA	-	Fakulti Kejuruteraan Awam dan Sumber Alam
GAC	-	Granular Activated Carbon
HLR	-	Hydraulic Retention Time
JBA	-	Jabatan Bekalan Air
MCL	-	Maximum contaminant level
MCLG	-	Maximum contaminant level goal
Mg/L	-	Milligram per liter
SSF	-	Slow Sand Filtration
TC	-	Total Coliform
TSS	-	Total Suspended Solids
UNICEF	-	United Nations Children's Fund
WHO	-	World Health Organisation

CHAPTER 1

INTRODUCTION

1.1 Introduction

The growth in Malaysia's population and expansion in urbanization, industrialization and irrigated agriculture are imposing growing demands and pressure on water resources, besides contributing to rising water pollution. Moreover, insufficient of the water quality service is extremely leading to poverty. As estimated in the Global Water Supply and Sanitation Assessment 2000 Report by World Health Organisation (WHO) and United Nations Children's Fund (UNICEF), globally, in the year 2000, 1.1 billion people had no access to improved water supply and 2.4 billion were without access to improved sanitation. Two thirds of people without access to improved water supply and approximately 80 per cent of those without access to improved sanitation in the world live in Asia. An estimated 670 million people in Asia lack access to improved water supply, while an estimated 1.9 billion lack adequate sanitation, representing 18 and 52 per cent of the region's population, respectively. According to World Health Organization (WHO, 2002), there were estimated 4 billion cases of diarrhoea and 2.2 million deaths annually. The consumption of unsafe water has been implicated as one of the major causes of this disease. Most gradual deterioration of water quality was resulted by the increase in human populations and urbanization (Ho, K.C. & Hui, C.C. 2001).

Nowdays, people are concern with the presence of pollutants such as heavy metals and toxic chemical in their daily drinking water.

Consequently, the majority of rural communities are still drinking superficial water that does not meet the required standard of quality, causing serious health problems. Filtration is one of the processes to ensure our drinking water is safe from physical contamination. Filtration is the mechanical removal of turbidity particles by passing the water through a porous medium, which is either a granular bed or a membrane. Purpose of filtration is to remove all the turbidity particles carried over from the sedimentation phase, thus producing sparkling clear water with almost zero turbidity. Turbidity and odour is the main causes faced by the rural area communities and the possibility of heavy metals, pathogens and other virus especially faecal coliform is also the main concerns for water treatment. Meanwhile, water treatment plant in Malaysia is focusing on partly of the treatment process such as aeration, coagulation, rapid sand filter and disinfection which is doubtful of the quality for to be served to the communities. As the consequent of that process, in the disinfection treatment method of chlorination will be used in a high dosage and will give effect to user and expensive to treat.

Therefore, this study is to investigate the potential of slow sand filtration as a biofiltration by adding natural material (coconut coir pith) as a medium to filter raw water as to reduce turbidity, total suspended solid, heavy metal and presence of pathogen and feacal coliform and also to reduce chemical additive in the disinfection process which is harmful to the communities. By using the slow sand filtration, pollution can be reduce because of the material being used are mostly from natural resources. According to Slezak and Sims, 1984 as reported in Water Treatment: Principles and Design, a survey conducted in the early 1980s identified less than 50 operating slow sand filtration plants in United States [for comparison, there are more than 50,000 community water systems in the United States (U.S EPA, 2001)]. Slow sand filtration however, does have some advantages over rapid filtration under certain circumstances and has received interest in recent years because of the simplicity of operation. In addition, slow sand filtration continues to be used successfully in Europe, including facilities supplying large communities such as London and Amsterdam (Joslin, 1997). Compared to rapid filtration, slow filtration is more inexpensive and reliable process but required highly skilled operators and also does not need electricity resource to be operated. Therefore, slow sand filtration is very suitable for rural areas that are far for electricity point. Even though slow sand filter achieved a high level of pathogens removals in water treatment process, by adding coconut coir pith as a activated carbon filter medium (Granular Activated Carbon) in slow sand filter which can produced high quality of water and increased the performance of the filter.

Therefore, this study will investigate the potential and effectiveness of activated carbon from coconut applied as medium in slow sand filter to treat and remove all those pollutant substances from water particularly to water intake nearest to pollutant sources.

1.2 Problem Statement

Slow sand filters are used in water purification for treating raw water to produce a potable product. In this study, there are several problem statements to be overview:

i. The conventional filtration in water treatment process is using too high dosage of chlorine

ii. To compare the effectiveness conventional SSF's (without adding Activated Carbon (AC)) and integrated SSF's (assimilated with Activated Carbon (AC))The raw water is turbid with suspended organic, inorganic matter and pathogenic organism.

1.3 Objectives of the study

The aim of this study is to investigate the effectiveness Slow Sand Filtration in treating raw water which are water sample taken from JBA. By carried out this study, the objectives below can be achieve:

i. The understanding description of the complex and fundamental interactions between the biological and physical process of operating in slow sand filters.
ii. To study the effectiveness in removing suspended solids organic, inorganic matter and pathogenic organism to obtain level of quality water.
iii. To determine the reduction of the turbidity, suspended solid and chemical use in treated water.
iv. To investigate the effectiveness additional of coconut coir pith as Granular Activated Carbon (GAC) in SSF to treat raw water.

1.4 Significance of the Study

Significance of SSF study divided into two categories which are effect of the applicability and commercialization potential. Effect of SSF study for the communities is there will be in natural and biological process to aid the filtration process. Meanwhile, for the applicability of SSF study are this water filtration process is one of reliable process and it is inexpensive to build and need low maintenance and also SSF's suitable in the rural area. While for the commercialization potential of SSF's is the usage of the water should used directly from the tap and useful in rural area because commonly in that area there will be no direct piping of water supply from JBA and also SSF process is useful for the used in factories to lower the cost of the usage of water.

1.5 Scope of Study

The scope of this study is to compare the conventional slow sand filtration with integrated slow sand filtration assimilate with the coconut coir pith as GAC layer in the filter bed. For this filtration process, sample of the raw water is taken from JBA from water treatment plant (WTP) at Semambu. Sample raw water from JBA was tested is sample water from the process of after flocculation. For the testing of the filtration, two pilot models of filter drum will be built and the material used are washed sand (0.15mm – 0.3mm), gravel sand (2mm-5mm) and coconut coir pith as GAC (>5mm). Laboratory testing to assess and evaluate the BOD, COD, turbidity, pH, total coli form, E. coli Iron(Fe), Copper(Cu) and Cadmium(Cd) in water samples which conducted at Laboratory FKASA, UMP.

CHAPTER 2

LITERATURE REVIEW

2.1 Importance of Water Treatment

The key to increase human productivity and long life is good quality water (Urbansky, E.T. & Magnuson, M.L. 2002). The provision of good quality household drinking water is often regarded as an important means of improving health (Moyo, S., Wright, J., Ndamba, J. & Gundry, S. 2004). Water is a key component in determining the quality of our lives. Today, people are concerned about the quality of the water they drink. Although water covers more than 70% of the Earth, only 1% of the Earth's water is available as a source of drinking. Water is known as a natural solvent. Before it reaches the consumer's tap, it comes into contact with many different substances, including organic and inorganic matter, chemicals, and other contaminants. Thus, water needs to be treated. Water with standard quality is used for drinking, washing, industrial and agricultural activities and others. Water quality varies from source to source and quality requirement varies according to its usage (Sastry *et al.*, 1996). In earlier times, man used water from natural sources. In order to get more or better quality of water, man moved to other sources. Man's earliest standards on water quality were such as free from mud, bad taste and odor. However, an increase in man-made water pollution, the development of technical and public health science, as well as the consumers' greater need for clean water contributed to the development of the water purification technology (Wegelin, 1996).

2.2 Filtration

Filtration is a mechanical removal of turbidity particles by passing the water through a porous medium, which is either a granular bed or a membrane. Filtration's purpose is to remove all the turbidity particles carried over from the sedimentation phase, thus producing sparkling clear water with almost zero turbidity (Darshan Singh Sarai, 2006). Water filtration process may reduce the concentration of particulate matter including suspended solid particles, parasites, bacteria, algae, viruses and fungi (Wikipedia, 2010). Filtered water is the main source of safe and reliable drinking water. According to a World Health Organization, 2007 as reported in Wikipedia, 1.1 billion people lack access to an improved drinking water supply, 88% of the 4 billion annual cases of diarrheal disease are attributed to unsafe water and inadequate sanitation and hygiene, and 1.8 million people die from diarrheal diseases each year. The WHO estimates that 94% of these diarrheal cases are preventable through modifications to the environment, including access to safe water. Simple techniques for treating water at home, such as chlorination, filters, and solar disinfection, and storing it in safe containers could save a huge number of lives each year (World Health Organization and UNICEF, 2005). Reducing deaths from waterborne diseases is a major public health goal in developing countries.

2.3 Granular Media Filtration

A granular media filter, generally, consists of rectangular concrete structure with 4-feet-deep media formed of sand or combination of sand, garnet, anthracite (crushed hard coal), and activated carbon. The media are supported by a layer of gravel. Under the gravel is a drain system for the drainage of filter effluent, called filtrate. Mostly, a small amount of cationic polymer is applied to the filter influent for micro flocculation. Polymer and turbidity particles form a very fine floc that accumulates on the top of the filter media and forms a straining mat (also called a surface cake) that removes turbidity. Turbidity is removed by two mechanism, straining and adsorption. Adsorption is acquiring the turbidity particles on the surface of micro floc. Most of the turbidity is removed in the top few inches of media.

There is a slightly high turbidity during the first 10 to 15 minutes of the filtration because the mat is not effectively formed. This is known as the ripening period, after which filtration is adequate. When there is too much build-up of the surface mat and filter interstices are plugged up, the rate of filtration decreases, and turbidity starts going up. At this point, the filter needs backwashing.

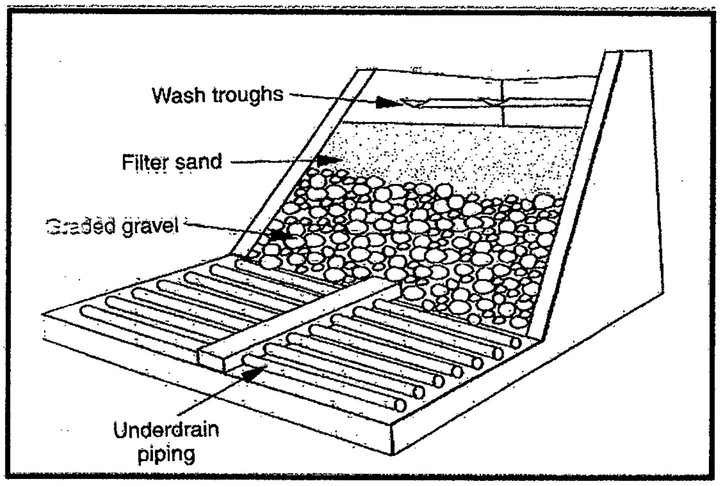

Figure 2.1: Vertical section of a sand filter (Sources: Water Treatment: Principles and Practices of Water Supply Operation, published by American Water Works Association, 1995

Backwashing is the removal of filtered-out turbidity by reversing the flow through the filter (i.e., from the bottom upward). The time period from beginning filtration to the filter wash is called a filter run. The period from the start of filtration to the end of the backwashing is called a filter cycle. Turbidity of the filter effluent and the resistance to flow, called head loss, are monitored continuously to determine the backwashing time and the filter performance. Generally, a washed filter is taken out of service for at least 30 minutes for the proper settling of media before putting it back into operation.

A good filter operation removes more than 99 percent of the feed water turbidity and produces a sparkling clear water with turbidity as low as 0.1 NTU or less.

2.4 Slow Sand Filter

The world's oldest water treatment system is known as Slow Sand Filtration (SSF). Slow sand filtration may be characterized as a passive process in that it occurs without operator intervention. Furthermore, the biology of slow sand filters that are used world-wide to make fresh water safe for drinking by the removal of many impurities, including pathogenic organisms and toxic chemicals. According to Weber-Shirk & Dick as reported by (Wotton, 2002), slow sand filtration is dependent on both physic-chemical and biological mechanism and uses processes that occur in natural bodies with sand substrata. The basic component of a slow sand filter is supernatant water layer, sand bed, underdrain system. Slow sand filters usually consist of a concrete tanks (of area > 1000 m^2 in water treatment works, but smaller in rural scale application) having drains built into their base. The layer of the filtration are from the base is covered with porous bricks cobbles and then layer of sand on top of them as shown in Figure 2.2 (Wotton, Introduction of slow sand filtration, 2002). The filter sand is typically a bed 0.9

to 1.5 m (3 to 5 ft) deep and is less uniform than the media specified for the rapid filters. The low filtration rate, coupled with the use of smaller sand (usually 0.30 and 0.45mm in diameter) than that used in rapid filters, causes particles to be removed in the top few centimeters of the bed (John C. Crittenden, 2005). The surface of the bed forms a mat of material, called a schmutzdecke. The schmutzdecke forms an additional filtration layer, physically straining smaller particles from the influent water. Sample of raw water generally are from river or reservoir and drains through the sand by gravity (at rate depending on conditions, but on an average at 0.1 – 0.3m h^{-1}) and exist to the drains in the filtration.

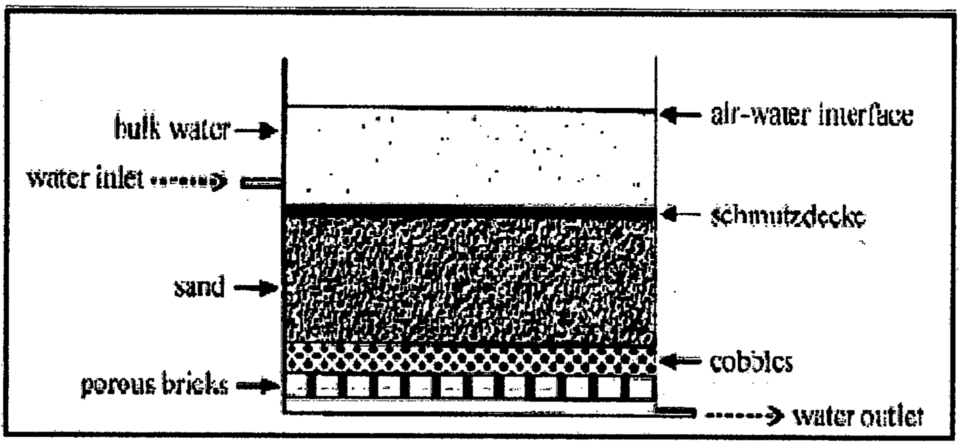

Figure 2.2: A cross-sectional diagram of a typical slow sand filter bed

2.4.1 Description of Slow Sand Filter

Application of SSF is a process where water slowly passing through a bed porous media which is allowing biological and chemical treatment processes to clean water. Typically in drinking water treatment applications it can be represented as illustrated in Figure 2 (Campos, 2002).

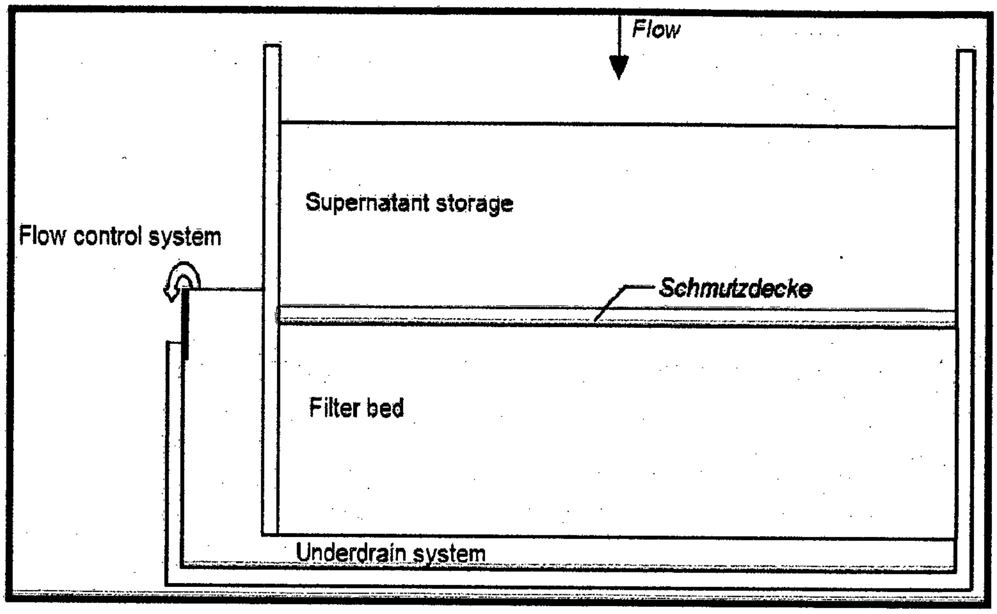

Figure 2.3: Slow Sand Filter Diagram

While the processes operating in SSF are extremely complex, the basic components and operational requirements of SSF can be reduced to the:

- supernatant storage;
- filter bed;
- underdrain system; and
- flow control system.

i. Supernatant Storage

The supernatant storage above the filter bed has historically been designed to hold 3 - 24 hours of water capacity for the water filtration system. The large storage capacity provides for equilibration of influent water quality, sedimentation of heavy particles and time for biological action to take place. Although some water treatment takes place in this reservoir, the primary purpose of this water is to provide driving head to push water through the filter bed, underdrain, and flow control systems. This can be viewed as analogous to the injection well water column in managed aquifer recharge (MAR) applications.

ii. Filter Bed.

Most of the water quality treatment processes occur in the filter bed. The filter bed is typically designed with a uniform media of small effective size grains at all bed depths. Sand is the usual filter material because of its low cost. This media must be thoroughly cleaned before use as a filter bed. The small, uniform grain size produces a filter bed that is highly effective for capturing particles, pathogens, has many small pores for sedimentation, and contains a high surface area for attachment and biological growth. The long hydraulic retention time permits the formation of a substantial biological community. As the water passes down through the media bed, the sand layers near the surface provide the most intense treatment zone where contaminants are removed and bio-adsorption and biodegradation occur. This treatment layer is often termed the schmutzdecke. The schmutzdecke initially develops over a short period of several weeks until filter maturity has occurred and only then is full treatment capacity realised. In MAR applications, the filter bed can be viewed as similar in properties to the near well area of the unconsolidated aquifer.

iii. Underdrain System.

The third component of a SSF is the underdrain system which is designed to support the filter bed, to provide a uniform flow rate and to provide a low velocity, low headloss means of draining the filtered water. An improperly designed or installed underdrain system can result in short circuiting through the filter bed. The underdrain system is an operational component of SSF.