Faculty of Resource Science and Technology

# OPTIMIZATION OF THE BIOFILTER IN THE GREYWATER TREATMENT

## *Temperature of the biofilter chamber*

Syarifah Shyfarina Bt. S. Mohamad Salleh

Bachelor of Science with Honours
(Resource Chemistry)
2006

# OPTIMIZATION OF THE BIOFILTER IN THE GREYWATER TREATMENT

## *Temperature of the biofilter chamber*

**Syarifah Shyfarina Bt. S. Mohamad Salleh**

**A dissertation submitted in partial fulfilment of the requirements for the degree of Bachelor of Science.**

**Faculty of Resource Science and Technology**
**UNUVERSITI MALAYSIA SARAWAK**
**May 2006**

# DECLARATION

**No portion of the work referred to in this dissertation has been submitted in support of an application for another degree of qualification of this or any other university of higher learning.**

Syarifah Shyfarina Bt. S. Mohamad Salleh

Resource Chemistry Programmed

Faculty of Resource Science and Technology

Universiti Malaysia Sarawak

# ACKNOWLEDGEMENTS

First of all I would like to dedicate my special thanks and sincere appreciation to my supervisor Assoc. Prof. Dr. Lau Seng. His guidance and helpful criticism throughout this research are very much appreciated.

I also would like to enlarge my sincerest and warmest thanks to Ms. Cindy Tan for her advice, co-operation and helping me regarding my research. Special thanks to all lectures of Faculty of Resource Science and Technology as well as the lab assistants of Institute of Biodiversity and Environmental Conservation (IBEC).

Last but not least, not forgetting to all my friends Kimberly, Cerollina, Teh, Roland Laiping and others. Thank you so much for all your invaluable help, support and encouragement during my research. May God bless you, guys!!!

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| Ecosan | Ecological Sanitation |
| BOD | Biochemical Oxygen Demand |
| COD | Chemical Oxygen Demand |
| TOC | Total Organic Carbon |
| ANOVA | Analysis of Variance |

# Optimization of the Biofilter in the Greywater Treatment System

## *Temperature of the Biofilter System*

**Syarifah Shyfarina Bt. S. Mohamad Salleh**

Resource Chemistry
Faculty of Resource Science & Technology
Universiti Malaysia Sarawak

## ABSTRACT

The objective for this study was to maximize the removal of BOD materials in wastewater through the optimization of the biofilter. In this study, continuous-flow column experiments were performed to evaluate factors affecting organic matter removal in biofilters. Columns were constructed from 0.67m acrylictubling plastic (95 mm outer, 84 mm inner in diameter) filled with the crushed red bricks (2-4 mm in diameter) as a filter media. Wastewater samples, analyzed initially were supplied continuously at the rate of approximately 90-110 mL/min per column. The temperature selected for the studies were 15°C (mean temperature = 15.3°C), 24°C (mean temperature =24.2°C) and 35°C (mean temperature = 35.5°C). The results of the analysis of this study showed that the most efficient temperature for BOD removal was at 24°C (55.81%), followed by temperature 35°C (49.25%) and 15°C (38.10%).

**Keywords:** Wastewater; Biofilter; Temperature; BOD removal

## *ABSTRAK*

*Objektif bagi kajian ini adalah untuk meningkatkan kadar penyingkiran dari bahan-bahan BOD dalam sisa air melalui pengoptimaan bioturasan. Dalam kajian ini, eksperimen kolum aliran berterusan dijalankan untuk menilai faktor-faktor yang mempengaruhi penyingkiran bahan-bahan organik di dalam bioturasan. Kolum dibina daripada 0.67m plastik akrilik (95 mm luaran, 84 mm dalaman; dalam diameter) dan diisi dengan pecahan bata-batu merah (2-4 mm; diameter bata) yang bertindak sebagai media turasan. Pada mulanya, sampel-sampel air untuk dianalisis dibekalkan secara berterusan pada kadar lebih kurang 90-110 mL/min/kolum. Suhu yang telah dipilih dalam kajian ini adalah pada 15℃ (suhu purata = 15.3 ℃), 24 ℃ (suhu purata = 24.2 ℃) dan 35 ℃ (suhu purata = 35.5℃). Hasil dari kajian ini menunjukan suhu yang paling efisien bagi pengeluaran BOD adalah pada 24 ℃ (55.81%), diikuti suhu pada 35 ℃ (49.25%) dan 15 ℃ (38.10%).*

***Kata kunci:*** *Sisa air; Bioturasan; Suhu; Penyingkiran BOD*

# CHAPTER 1
# INTRODUCTION

## 1.1 BACKGROUND

The water we use never really goes away. In fact, there never will be any more or any less water on earth than there is right now, which means that all of the wastewater generated by our communities each day from homes, farms, businesses, and factories eventually returns to the environment to be used again. So, when wastewater receives inadequate treatment, the overall quality of the world's water supply suffers.

Wastewater includes sewage, stormwater, and water that have been used for various purposes around the community. Unless properly treated, wastewater can harm public health and the environment. Most communities generate wastewater from both residential and non-residential sources. There are two types of domestic sewage which are blackwater, or wastewater from toilets, and greywater, which is wastewater from all sources except toilets. Blackwater and greywater have different characteristics, but both contain pollutants and disease-causing agents that require treatment.

Greywater consists of wastewater from laundry, kitchens, baths, washing basins, and other in-house wastewater outlets other than toilets. Greywater has medium to high contents of organic matter (BOD), low contents of nitrogen (N), and moderate contents of phosphorus (P). Greywater has a low content of bacteria (*E.coli*). The greywater in Kuching is also expected to have high contents of oil or grease, due to local cooking habits. The amount of greywater discharge is generally estimated at approximately 150-250 l/cap/day (NREB/DID, 2004).

Non-residential wastewater in small communities is generated by such diverse sources as offices, businesses, department stores, restaurants, schools, hospitals, farms, manufacturers, and other commercial, industrial, and institutional entities. Stormwater is a non-residential source and carries trash and other pollutants from streets, as well as pesticides and fertilizers from yards and fields.

According to Taylor *et al.* (1997), they found in wastewater containing pollutants such as organisms, pathogens, organic matter, oil and grease, inorganic, nutrients, solid, and gases. Organic matter is a pollutant from agricultural and industries resources. Organic compounds normally are some combination of carbon, hydrogen, oxygen, nitrogen, and other elements. Many organics are proteins, carbohydrates, or fats and are biodegradable, which means they can be consumed and broken down by organisms. However, even biodegradable materials can cause pollution. In fact, too much organic matter in wastewater can be devastating to receiving waters.

Large amounts of biodegradable materials are dangerous to lakes, streams, and oceans, because organisms use dissolved oxygen in the water to break down the wastes. This can reduce or deplete the supply of oxygen in the water needed by aquatic life, resulting in fish kills, odours, and overall degradation of water quality. The amount of oxygen organisms need to break down wastes in wastewater is referred to as the biochemical oxygen demand (BOD) and is one of the measurements used to assess overall wastewater strength.

Some organic compounds are more stable than others and cannot be quickly broken down by organisms, posing an additional challenge for treatment. This is true of many synthetic organic compounds developed for agriculture and industry. In addition, certain synthetic organics are highly toxic. Pesticides and herbicides are toxic to humans, fish, and aquatic plants and often are disposed of improperly in drains or carried in stormwater. In receiving waters, they kill or contaminate fish, making them unfit to eat. They also can damage processes in treatment plants. Benzene and toluene are two toxic organic compounds found in some solvents, pesticides, and other products. New synthetic organic compounds are being developed all the time, which can complicate treatment efforts.

Meanwhile, inorganic is a pollutant comes from domestic and industrial sources. Inorganic minerals, metals, and compounds, such as sodium, potassium, calcium, magnesium, cadmium, copper, lead, nickel, and zinc are common in wastewater from both residential and non-residential sources. They can originate from a variety of sources in the community including industrial and commercial sources, stormwater, inflow and infiltration from cracked pipes, and leaky manhole covers. Most inorganic substances are relatively stable, and cannot be broken down easily by organisms in wastewater. Large amounts of many inorganic substances can contaminate soil and water. Some are toxic to animals and humans and may accumulate in the environment.

Typical wastewater treatments in Malaysia are divided into two systems. The systems are conventional centralized systems and decentralized systems. Conventional sewerage and wastewater treatment systems rely upon a dependable water supply in order to function correctly. In many cities, where there is increasing pressure upon available water resources this can no longer be taken for granted.

The main limitations of conventional centralized systems are high construction and maintenance costs, the absence of a dependable water supply can prevent proper operation of the sewerage system. Moreover the collected sewage has to be treated which adds to the overall cost of the sanitation system sometimes very significantly, and as existing networks in developing countries, primarily serve the rich, people have begun to recognize that sewerage systems do not allow for the recovery and recycling of valuable nutrients into the food production loop.

The decentralized systems concept is to provide a framework for producing alternative systems. These systems which are also more fiscally reasonable, more socially responsible, and more environmentally benign than conventional practice. Stated most simply, the decentralized systems concept holds that wastewater should be treated as close to where it is generated as practical. In general, it is suggested that septic tanks indeed be used to intercept the flow from each generator at the wastewater source, but effluent from these tanks may be routed to further treatment processes, and these may be deployed at various levels of flow aggregation.

Many considerations would determine how close to the source of generation it is practical to address treatment and disposal. One very important factor is if and how the wastewater could be reused in a beneficial manner, challenging the very concepts of wastewater and disposal. Other considerations include topography, soil conditions, development density, and type of land use.

The advantages of decentralized systems are it is easier and faster to install. Moreover, soil in the trenches is not as likely to be compacted. So, it is less expensive in areas where gravel must be transported over a long distance.

This system is allowed for lower intrusion of soil and silts into the drainfield and thereby extends the useful life of the drainfields. Other advantages are the inspection of the chambers is easier and it requires a smaller footprint. Some states allow up to a 50 percent reduction in drainfield size compared to conventional gravel drainfield systems (Crites and Tchobanoglous, 1998).

Ecological Sanitation is a systemic approach and an attitude; single technologies are only means to an end and may range from near-natural wastewater treatment techniques to compost toilets, simple household installations to complex, mainly decentralized systems. These technologies are not ecological per se but only in relation to the observed environment. They are picked from the whole range of available conventional, modern and traditional technical options, combining them to Ecosan systems (Langergraber and Muellegger, 2005).

According to IRC International Water and Sanitation Centre (2005), Ecological Sanitation (Ecosan) is based on the idea that urine, faeces and water are resources in an ecological loop. It is an approach that seeks to protect public health, prevent pollution and at the same time return valuable nutrients and humus to the soil. This recycling of nutrients helps to ensure food security.

In ecological sanitation, urine and faeces are separated at source and are not mixed with water. Hence this sanitation solution avoids the contamination of large volumes of water with pathogens. In addition, the separation of urine and faeces make it easier to recover and recycle nutrients such as phosphorous and nitrogen. After dilution and/or processing separated urine can be applied to the soil as a hygienic fertiliser. Faeces, on the other hand, can be safely composted and allows for the integration of organic waste treatment into food production.

Ecological Sanitation can provide affordable sanitation options for all. It covers a wide range of toilet designs as well as different techniques for the collection and treatment of urine and faeces. Ecological Sanitation includes low- and high-technology solutions for rural and urban settings. It allows for central and/or decentralised management and can be dry and/or waterborne. This means that appropriate sanitation solutions can be developed for a range of different situations. So, Ecosan is the ecologically sustainable approach.

## 1.2 HYPOTHESIS

The hypothesis for this study was the functions and efficiency of the biofilter in removing BOD materials can be enhanced by optimizing the temperature of the biofilter and the wastewater.

## 1.3 OBJECTIVES

The general objective for this study was to maximize the removal of BOD materials in wastewater through the optimization of the biofilter. To be specific, this study was carried to determine the relationship between the temperature in the biofilter as well as the wastewater and the removal of BOD materials in the biofilter.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 WASTEWATER CHARACTERISTICS

Wastewater is generally defined as "the combination of the liquid and water, carried wastes from residence, commercial buildings, and industrial plant together with any greywater, surface water and stormwater that may be present" (Corbit, 1990). The wastewater characteristics are divided into three categories which are physical characteristic, chemical characteristic, and biological characteristic.

### 2.1.1 Physical Characteristics

The principal physical characteristics of a wastewater are its solids content, colour, odour, and temperature. The total solids in a wastewater consist of the insoluble or suspended solids and the soluble compounds dissolved in the water. Meanwhile, colour is a qualitative characteristic that can be used to assess the general condition of wastewater. For example, if the colour is dark grey or black, the wastewater typically is septic, having under-gone extensive bacterial decomposition under anaerobic (in the absence of oxygen) conditions.

The odour of fresh wastewater is usually not offensive, but a variety of odorous compounds are released when wastewater is decomposed biologically under anaerobic conditions. The temperature of wastewater commonly is higher than that of the water supply because of the addition of warm water from municipal use. The temperature of wastewater are various, from about 7°C to 8°C in cold regions while 13°C to 24°C in warmer regions (Linsley *et al.*, 1992).

### 2.1.2 Chemical Characteristics

The chemical characteristics include inorganic and organic chemical characteristics. The inorganic chemical characteristics are the measurements of gases, such as hydrogen sulphide, oxygen, methane, and carbon dioxide. These gases are made to help in the operation of the system. Measurements of dissolved oxygen made to monitor and control aerobic biological treatment processes. Methane and carbon dioxide measurements are used in connection with the operation of anaerobic digesters. While organic chemical characteristics are to measure *biochemical oxygen demand* (BOD), *chemical oxygen demand* (COD), and *total organic carbon* (TOC) (Tchobanoglous and Burton, 1991).

### 2.1.3 Biological Characteristics

The biological characteristics are the principal groups of organisms found in surface water and wastewater include bacteria, fungi, algae, protozoa, plants, animals, and viruses. Most bacteria are classified as eubacteria while the category *protista* are algae, fungi, and protozoa. Plants are classified as multicellular eukaryotic animals (Stanier *et al*., 1986). Viruses are classified separately according to the host infected. Both in nature and in treatment plants, their characteristics, functions, metabolism, and synthesis must be understood because of the extensive and fundamental role played by bacteria in the decomposition and stabilization of organic matter.

## 2.2 ECOLOGICAL SANITATION (Ecosan)

The current research in wastewater treatment is Ecological Sanitation (Ecosan). The principles underlying Ecosan are not novel. In different cultures, sanitation systems based on ecological principles have been used for hundreds of years. Ecosan systems are still widely used in parts of East and Southeast Asia. In Western countries, this option was largely abandoned as "flush and discharge" became the norm. Only in recent years, there has been a revival of interest in Ecosan (Esrey *et al*., 1998).

The problems that have to be solved in developing and industrialized countries are different. In developing countries, the main focus of action is to reduce health risks in urban, peri-urban and rural areas. Ecosan concepts save water resources and due to their re-use orientation have benefits for agriculture. In industrialized countries, the main focus is on rural areas and on the reduction of environmental impacts. The comparison of investment and operating costs shows that conventional systems for rural areas are the most expensive option mainly due to the sewer lines needed (Lechner and Langergraber, 2004). Especially the operating costs of source separating systems are lower compared to conventional systems where all the wastewater is collected and treated (Müllegger *et al*., 2004). In addition to the more ecological sound sanitation and their sustainability re-use oriented systems are therefore also economically advantageous.

The example Ecosan project in Malaysia is the Ecological Sanitation Pilot Project at Hui Sing Garden, Kuching, Sarawak. In the other countries, Ecosan project are held in the Tilaran mountain in of northwest Costa Rica (Clark *et al*., 2000), the Svanholm Community in Denmark (la Cour Jansen and Koldby, 2004), Sund in Finland (Malmén *et al*., 2003), and Lübeck-Flintenbreite in German (Wendland and Oldenburg, 2004).

### 2.2.1 Advantages of Ecosan

The advantages of Ecosan can be summarised as follows (GTZ, 2002):

- Ecosan improves health by minimizing the introduction of pathogens from human excreta into the water cycle.
- Ecosan promotes a safe and hygienic recycling to use valuable nutrients in human excreta.
- Ecosan conserves the natural resources through reducing the water consumption, substitution of chemical fertilizers and minimizes the water pollution.
- Ecosan gives preference to modular, decentralised, separated-flow systems for more appropriate and cost-effective solutions.

# CHAPTER 3

# METHODOLOGY

## 3.1 SAMPLE COLLECTION AND PREPARATION

### 3.1.1 Water Sampling

Wastewaters were collected in Universiti Malaysia Sarawak, (UNIMAS) at Kenanga Greywater Treatment Facility (KGTF). The content of BOD in the wastewaters varied with the sampling day.

### 3.1.2 Continuous-Flow Column Experiments

The methodology based on methods as reported by Farabegoli *et al.*, (2003). Continuous-flow column experiments were performed to evaluate factors affecting organic matter removal in biofilters. Columns were constructed 0.67m acrylictubling plastic (diameter 95 mm outer, 84mm inner) and filled with filter media. In this study, only one type of media was using which where crushed red bricks (2-4mm).

Wastewater samples, analyzed initially were supplied continuously at the rate of approximately 90-110 mL $min^{-1}$ per column (equivalent to a nominal retention time in the columns of 12 - 14 h) using a constant-head feeding tank. The water level in the feeding tank was kept constant by continuous pumping from a continuously stirred storage tank kept at ground level. The columns were kept water saturated, as the effluent levels of the columns were set just above the surface of the media in the columns. The effluents from each column were collected daily and the volumes were measured to estimate actual loading. An aliquot filtered through Whatman GF/C filters and analyzed.

Reading of the thermometer was taken in three different levels, which were at the top, the middle as well as the bottom of the biofilter. Different temperatures were tested in biofilter systems also in the water sample. The temperature selected for the studies were 15°C, 24°C and 35°C.

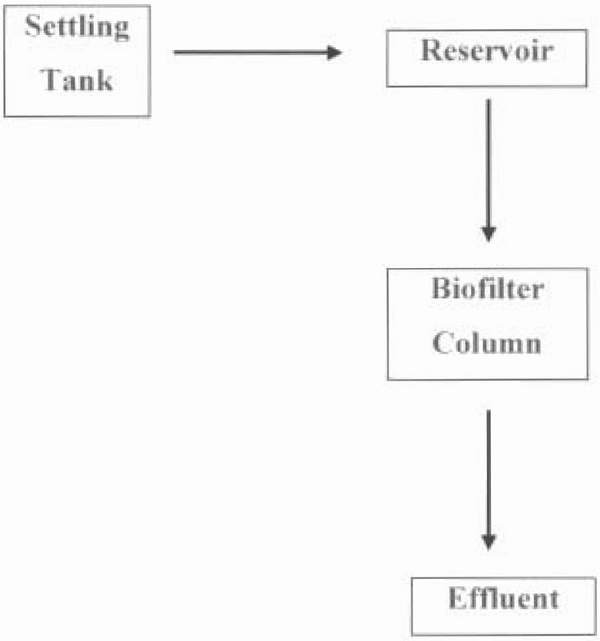

**Figure 1:** Schematic diagram of biofilter system.

## 3.2 ANALYTICAL METHOD

Influent and effluent samples were analyzed for Biochemical Oxygen Demand (BOD). The $BOD_5$ of the wastewater test samples were determined by the standard APHA measurement method (American Public Health Association, 1992). Hanna Dissolved Oxygen kit was used.

### 3.2.1 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand is essentially a measure of the amount of dissolved oxygen in the water consumed during the bio-degradation of the organic pollutants. It is determined in the laboratory by the amount of oxygen consumed in 5 days under controlled conditions by the microorganisms added deliberately to the water test sample to assimilate and bio-oxidize the organics ($BOD_5$) (Tan and Lim, 2005). The BOD test is the common test used in the field of wastewater treatment. The aerobic biological decomposition of an organic waste will continue until all of the waste is consumed, if sufficient oxygen is available (Crites and Tchobanoglous, 1998).

According to Tchobanoglous and Schroeder (1985), in the standard test for BOD, a small sample of the wastewater to be tested is placed in a BOD bottle (vol. 300 mL). The bottle then is filled with dilution water saturated in oxygen and containing the nutrients required for biological growth. The oxygen concentration in the bottle is measured before the bottle is stopper (initial BOD). After incubating the bottle for 5 days at $20^{\circ}C$, the dissolved-oxygen concentration is measured again (final BOD). The BOD of the sample is the difference in the dissolved-oxygen concentration values (mg/L), divided by the decimal fraction of sample used. The computed BOD value is known as the 5-days, $20^{\circ}C$ biochemical oxygen demand. When testing waters with low concentrations of microorganisms, a seeded BOD test is conducted.

### 3.2.2 Calculation

For each test bottle meeting the 2.0-mg/L minimum dissolved oxygen (DO) depletion and the 1.0-mg/L residual DO, calculate $BOD_5$ as follows:

When dilution water is not seeded:

$$BOD_5,\ mg/L = \frac{D_1 - D_2}{P}$$

When dilution water is seeded:

$$BOD_5,\ mg/L = \frac{(D_1 - D_2) - (B_1 - B_2)f}{P}$$

where:

$D_1$ = dissolved oxygen of diluted sample immediately after preparation, mg/L

$D_2$ = dissolved oxygen of diluted sample after 5 d incubation at 20°C, mg/L

$B_1$ = dissolved oxygen of seed control before incubation, mg/L

$B_2$ = dissolved oxygen of seed control after incubation, mg/L

$f$ = fraction of seeded dilution water volume in sample to volume of seeded dilution water in seed control

$P$ = fraction of wastewater sample volume to total combined volume