POLYCHAETE ASSISTED SAND FILTER IN TREATING SYNTHETIC WASTEWATER

by

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Thesis submitted in fulfillment of the requirements for the degree of Master of Science

September 2014

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UNIVERSITI SAINS MALAYSIA

2014

ACKNOWLEDGEMENT

First of all, I would like to thank the Almighty Allah for His blessing and His power for giving me opportunity in furthering my study and managed to complete this thesis. A number of people have made significant contributions to the preparation of this report. Their insights, advice and suggestions helped me a lot.

It is my great pleasure to acknowledge and I would like to record my grateful thanks to those in the University Sains Malaysia (USM) who have contributed greatly to this project especially my supervisor, Assoc. Prof. Dr. Mahammad Hakimi Ibrahim for his guidance and constant encouragement. He has been an excellent supervisor and has provided full support as well as advices, valuable suggestion and also constructive criticism that greatly influenced in my master research.

I would like to extend my heartiest thanks to Pak Ali bin Mohammad, who provided me with information that were used to help me develop my sand filter design. My gratitude also goes to Mr. Omar Ahmad, research officer of Centre for Marine and Coastal Studies, CEMAC, USM who has rendered assistance regarding polychaete species for my master research. Besides that, my master could not being completed without the help from all staff and lab assistants at School of Technology Industry, USM for their welcoming service.

Last, but not least, I thank my family especially my parents for educating me, for unconditional support and encouragement throughout my studies. Not to forget to my siblings, friends and others who help me and motivating me all the way through and for your endless love and support, encouragement and unparalleled help towards me. I love you all. Thank you and may Allah bless you all.

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LIST OF ABBREVIATIONS AND SYMBOLS

APHA	American Public Health Association
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
BP	Beach Sand Filter with Polychaete
BX	Beach Sand Filter without Polychaete
CEMAC	Centre for Marine and Coastal Studies
CL	Construction Sand Filter with 500 Polychaete/m^2
CH	Construction Sand Filter with 1500 Polychaete/m^2
CM	Construction Sand Filter with 1000 Polychaete/m^2
COSSF	Continually Operated Slow Sand Filter
CP	Construction Sand Filter with Polychaete
CP1	Construction Sand Filter with Polychaete scale 1
CP5	Construction Sand Filter with Polychaete scale 5
DO	Dissolved Oxygen
ECOPRO	Eco process Technology Research
IOSFF	Intermittently Operated Slow Sand Filter
NDEP	Nevada Division of Environmental Protection
NTU	Nephelometric Turbidity Units
PCLS	Pollution Control Law Series
RGF	Rapid Gravity Filter
RGR	Relative Growth Rate

S.D.	Standard Deviation
SGR	Specific Growth Rate
TERI	Tata Energy Research Institute
TSS	Total Suspended Solids
USEPA	US Environmental Protection Agency

PENURAS PASIR BERBANTUKAN POLYCHAETE DALAM MERAWAT AIR SISA TIRUAN

ABSTRAK

Kajian ini adalah mengenai penuras pasir berbantukan polychaete dalam merawat air sisa tiruan. Untuk menguji aplikasi konsep ini, penuras pasir berbantukan polychaete digunakan bagi menguji keupayaan mereka untuk merawat air sisa tiruan. Objektif utama dalam kajian ini adalah untuk mengkaji keupayaan penuras pasir dengan kehadiran polychaete untuk penapisan air sisa tiruan. Perbandingan antara prestasi pasir pantai dan pembinaan dalam penuras pasir berbantukan polychaete dalam penapisan air sisa tiruan juga telah dikaji selidik dari segi kadar perkolasi dan kualiti air. Selain itu, pertumbuhan dan daya hidup polychaete yang didokumenkan dengan tiga kepadatan polychaete yang berlainan (500, 100 dan 1500/m^2) selama 7 minggu. Penuras pasir berskala (1:5) juga dipelajari untutk menyiasat penggunaan penapis pasir dalam skala yang lebih besar. Keputusan kajian ini memberikan maklumat yang berguna mengenai kajian penuras pasir dengan kehadiran polychaete untuk penurasan air sisa berkaitan dengan kadar perkolasi, kualiti air, pertumbuhan dan daya hidup polychaete. Polychaete Juvana (*Perinereis nuntia*) telah digunakan sebagai komponen utama proses penurasan pasir dan ia telah digunakan pada kepadatan kawalan 1000 polychaete/m^2. Air sisa tiruan telah disediakan untuk penurasan dengan mencampurkan pelet ikan kering yang hancur dan air laut. Air sisa tiruan yang mengalir melalui penuras pasir berbantukan polychaete telah dirawat di mana tahap jumlah pepejal terampai (TSS) telah dikurangkan secara konsisten lebih daripada 70% oleh proses penurasan. pH, oksigen terlarut (DO) dan permintaan

oksigen biokimia (BOD) juga telah dikurangkan dengan ketara oleh proses penapisan oleh penuras pasir berbantukan polychaete. Walau bagaimanapun, bagi penuras pasir yang tidak berbantukan polychaete, jumlah pepejal terampai (TSS) diasingkan hanya pada 60% oleh proses penurasan. Kajian perbandingan ini jelas menunjukkan bahawa penuras pasir berbantukan polychaete mempunyai potensi yang tinggi untuk merawat air sisa daripada penuras pasir tanpa polychaete. Kedua-dua penuras yang menggunakan pasir pantai dan pembinaan menunjukkan prestasi yang sama dari segi kadar perkolasi dan juga ciri-ciri air sisa efluen di mana tiada perbezaan yang signifikan ($P \geq 0.05$) antara kedua-dua pasir. Kadar perkolasi efluen air sisa bagi penuras pasir pantai dan pembinaan mempunyai aliran yang sama, di mana penuras pasir pembinaan memberikan sedikit nilai kadar perkolasi yang lebih tinggi (0.26 L/m^2s) daripada penuras pasir pantai (0.24 L/m^2s). Oleh itu, pasir pantai dan pembinaan boleh digunakan sebagai medium untuk penuras pasir. Kajian ini membuktikan bahawa kepadatan bekalan polychaete mempengaruhi kadar penapisan, kualiti air sisa dan pertumbuhan dan daya hidup polychaetes. Ini disebabkan oleh kehadiran dan kuantiti polychaete. Kepadatan bekalan polychaete yang tinggi, 1500 polychaete/m^2 mempunyai DO, 4.25 mg/L dan kepekatan TSS, 182.04 mg/L yang lebih rendah. Sementara itu, kadar kepadatan bekalan polychaete yang rendah (CL), 500 polychaete/m^2 menghasilkan daya hidup polychaete yang lebih tinggi, (100%) berbanding dengan kepadatan bekalan polychaete yang sederhana, CM (81.11%) dan kepadatan bekalan polychate yang tinggi, CH (71.85%) selepas 7 minggu. Peratusan daya hidup polychaete menurun apabila kepadatan bekalan polychaete meningkat. Dari kerja ini, penuras pasir skala besar (1:5) adalah setanding dengan penuras pasir kecil kerana tiada perbezaan yang signifikan di antara kedua-dua penuras tersebut dalam kepekatan DO, TSS dan juga pertumbuhan dan daya hidup polychaete. Kesimpulannya, penuras pasir berbantukan polychaete boleh digunakan untuk merawat air sisa tiruan dalam proses penurasan.

POLYCHAETE ASSISTED SAND FILTER IN TREATING SYNTHETIC WASTEWATER

ABSTRACT

This study is about polychaete assisted sand filter in treating synthetic wastewater. To test the application of this concept, polychaete assisted sand filters were experimentally tested for their ability to treat synthetic wastewater. The main objective in this study was to examine the feasibility of polychaete assisted sand filter for synthetic wastewater filtration. The comparison between beach and construction sand in terms of percolation rate and water quality in polychaete assisted sand filtration of synthetic wastewater was also investigated. Besides that, the growth and survival of the polychaete at three different polychaete stocked density (500, 100 and 1500/m^2) after 7 weeks. Scale up (1:5) of the sand filter was also studied to investigate the application of sand filter in larger scale. The results of this study provided information on the study of polychaete assisted sand filter performance in relation to percolation rate, water quality of wastewater and also growth and survival of polychaete. Juvenile polychaete (*Perinereis nuntia*) was used in sand filter and stocked at a control density of 1000 polychaete/m^2. Synthetic wastewater was prepared for the filtration by mixing ground dried fish pellets and sea water. Synthetic wastewater percolating through polychaete assisted sand filter beds were reliably treated where total suspended solids (TSS) levels were consistently reduced by more than 70% by the process. pH, dissolved oxygen (DO) and biochemical oxygen demand (BOD) levels were also lowered significantly by the filtration process of polychaete assisted sand filter. However, for sand filter without

polychaete, the total suspended solid (TSS) was removed only 60% from the filtration process. This comparative study clearly indicated that the sand filtration stocked with polychaete has higher potential to treat wastewater than the sand filter without polychaete. Both beach and construction sand filters showed similar performance in terms of percolation rate and also water qualities of filtrate wastewater as there was no significant difference ($P \geq 0.05$) between both sand. The percolation rate effluent wastewater for sand filter using beach and construction sand had the same trend, where sand filter using construction sand gave slightly higher percolation rate value (0.26 L/m^2s) than sand filter using beach (0.24 L/m^2s). Thus, beach and construction sands can be used as medium bed for sand filter. In this study, it was proved that polychaete stocking density did affect percolation rate, water quality of wastewater and polychaetes growth and survival. This was due to the presence and quantity of polychaetes. Higher polychaete stocking density has lower DO and TSS concentration which were around 4.25 mg/L and 182.04 mg/L, meanwhile lower polychaete stocking density produced higher polychaete growth and survival compared to higher polychaete stocking density. The survival rate of polychaete after 7 weeks was lower at high polychaete stocking density, CH (71.85 %) in comparison to medium polychaete stocking density, CM (81.11 %) and low polychaete stocking density, CL (100 %). The percentage of survival of polychaete decreased as stocking density increased. From this work, scale up sand filter (1:5) was comparable with small (control) sand filter as there was no significant difference ($P \geq 0.05$) between small and larger sand filters in terms of pH, DO, TSS concentration and also polychaetes growth and survival. For the conclusion, polychaete assisted sand filters can be used to treat synthetic wastewater in filtration process.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Filtration is the designed passage of wastewater through a permeable medium either sand or an organic media, thus utilizing the principle of natural pollutant removal (Gabriele, 1986; Unger and Collins, 2008; Kubiak and Oszako 2011). This widely used technique in wastewater treatment is based on some simultaneously occurring phenomena, for example mechanical straining of undissolved suspended particles, flocculation, adsorption of colloidal matter and bacteriological-biological processes and removal of pollutants (particles, microorganisms, organic, and inorganic compounds) (Zaman et al., 2014).

Sand filters are usually used as the second step in wastewater treatment after solids in raw wastewater have been separated out in a septic tank, aerobic unit, or other sedimentation process (Naseer et al., 2010). Wastewater treated by sand filtration is usually colourless and odourless. Over the years, sand filters have proven to be a reliable technology when they are properly designed, constructed, and maintained. Their performance is relatively consistent and they have low operation and maintenance requirements (Pipeline, 1997). About 60 % of the sludge total organic C was removed by the filters. Nitrogen in the effluent from the filter was predominately organic, and nitrate concentrations were significant (Kristiansen and Cripps, 1996).

In relation to the effluent quality, cost efficacy and operational simplicity, slow sand filtration can be considered as one of the most promising post treatment options (Kumar and Shah, 2009). Various researchers investigated the effectiveness of slow sand filters for tertiary treatment of wastewater which are capable of removing BOD and SS, turbidity and total coliforms up to 86%, 68%, 88% and over 99%, respectively (Suhail, 1987). Sand filtration for wastewater treatment is an established technology that has attracted renewed interest due to its potential to satisfy many of the current needs for wastewater treatment (Wridge et al., 1996).

A few species of marine worms have been documented growing in prawn farm environments in uncontrolled ways like *Perinereis sp* (Fujioka, 2007). Polychaetes, segmented marine worms in the phylum annelida, have recently gained commercial importance as baits for sea fishing (sport angling) and more recently because it is now used as an aquaculture feed either live, in blast frozen form, or as a constituent of formulated feeds for maturation diet of shrimp brood stock (Olive, 1999).

Organisms that might feed on aquaculture related waste include deposit feeding detritivores such as polychaete worms. The potential for polychaete worms to ingest and assimilate fecal waste from Japanese flounder was reported by Honda and Kikuchi (2002). Sand filters are commonly used to treat waters in domestic (Campos, 2002) and aquaculture systems (Vigneswaran, 1999; Palacios and Timmons, 2001). These two concepts could be combined in a controlled way to sequester nutrients that would otherwise be wasted in prawn pond discharge waters, but before investing further in this pursuit there is a need to test the concept in a commercial environment (Palmer, 2011).

1.2 Problem Statement

The potential for environmental damage from nutrients in wastewater either from aquaculture or fish processing factory is well recognized and many researchers around the world are involved with developing new technologies to reduce the environmental footprint of intensive systems (Palmer, 2008). Sand filters are used to remove suspended solids from water and wastewater. Accumulation of biomass and deposition of suspended solids at the surface of a sand filter can lead to clogging of the filter media (Rodgers et al., 2004). This situation can be avoided by stocking polychaetes in the sand filter to help stop the sand filter bed from clogging by clearing the organic debris that would block the sand and stop the percolation of water.

The principle behind polychaete assisted sand filter (PASF) lies in the burrowing and feeding activities of the worms in the sand, and their ability to survive and grow on the deposited organic material. They appear to help maintain percolation through the sand filter whilst organic debris that is trapped by the sand directly and becomes their food (Palmer, 2010). With growing interest in polychaete (Brown et al., 2011) in wastewater treatment, technical and scientific knowledges of this process are continuously expanding, making this treatment a promising alternative wastewater treatment (Loehr, 1984).

Polychaete is relatively small in size among invertebrate marine organisms, although some species can attain length up to 6 meters (Roues and Pleijel, 2001). Their intermediate positions in food web (Fauchald and Jumars, 1979) make them less important by many researchers. However, their importance in natural ecosystem such as pollution determinator continues to receive further recognition (Reish and Gerlinger, 1997) because animals like polychaete, which can grow in polluted sediment has significant settled material and sludge, which can make use of this portion of wasted nutrient to create additional profit.

According to Chareonpanich et al. (1994), an attempt to treat the organically polluted sediment has been done by exploiting the biological activities of a deposit-feeding polychaete, *Capitella sp. I*. The head-down deep deposit-feeding polychaetes are also known for having strong effects on bioturbation and nutrient mineralization both by sediment reworking during non-selective feeding and by burrow irrigation (Papaspyrou et al., 2007).

Some recent authors in this area have suggested the use of local species to avoid unnecessary introductions that may result in environmental problems (Costa, 2006; Scaps, 2003). Most of these operations have focused on various species from the family Nereididae, which have proved amenable to intensive culture conditions (*Perinereis nuntia*: Poltana et al., 2007) and have been shown able to synthesize essential fatty acids necessary for the nutrition of marine fish and prawns (Olive, 1999; Costa et al., 2000).

Previous work from Palmer (2011) had shown that this physical and biological treatment combination can provide a new option for saline wastewater treatment, since the polychaetes help to prevent sand filter blocking with organic debris and offer a profitable by-product. The study done by Palmer involved only sand filtration beds in large scale (field work), not in small scale (lab) where polychaetes were stocked and cultured to help facilitate the broad-scale filtration process. Thus far there was also no study has been done in comparing the performance (percolation rate and water quality such as pH, salinity, DO, BOD, TSS) between sand filter stocked with polychaete and without polychaete for wastewater treatment.

Only one study had used polychaete in sand filtration for wastewater treatment, Palmer (2011). There is also no literature presented on comparison between beach and construction sand as medium bed. Most of previous researchers only used beach sand for polychaetes culture, while Palmer used construction sand as filter medium bed (Safarik et al., 2006). Palmer (2011) had applied high polychaete stocking densities (2000 and 6000 polychaete/m^2), while there was no application of stocking density as low as 500 polychaete/m^2 in polychaete assisted sand filter for the wastewater treatment. Lastly, comparison between small and larger sand filter with polychaete for lab scale is yet to be done by other researchers in treating wastewater, so the results might be different compared to commercial scale.

1.3 Objectives

This study essentially examines the feasibility of polychaete assisted sand filter to treat wastewater based on the following specific objectives:

1.3.1 To compare sand filter performance stocked with and without polychaete in terms of DO, TSS and BOD

1.3.2 To compare performance of beach and construction sand in polychaete assisted sand filter in terms of DO, TSS and BOD

1.3.3 To determine the growth and survival of polychaete with different polychaete stocking density

1.3.4 To evaluate the performance of larger scale polychaete assisted sand filter

1.4 Research Scope

The scope and purpose of this study was to examine the performance of polychaete assisted sand filter in terms of water quality, growth and survival of polychaete and to document this new treatment academically. This research was done as an option for saline wastewater treatment as local polychaete was used to prevent sand filter clogging with organic debris. However, this research does not focus on culturing the polychaete and the use of actual wastewater as material for the study. Furthermore, this research was done only in lab scale and using synthetic wastewater, consisting of mixed ground dried fish pellets and local sea water. The analyses for the research are percolation rate, water quality of wastewater as well as growth and survival of polychaete.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Wastewater Treatment

Wastewater treatment is a process in which the solids in wastewater are partially removed and partially changed by decomposition from complex highly putrescible organic solids to mineral or relatively stable organic solids. Treatment systems are designed to protect humans from contact with waste water; treat wastewater to minimize contamination of soils, lakes, rivers and groundwater; keep animals and insects from contact with waste water; and minimize the generation of foul odors (EPA, 2013). The extent of this change is dependent on the treatment processes involved. After all treatment processes have been completed, it is still necessary to dispose of the liquid and the solids which have been removed (Koshel et al., 1998).

In many cases a lack of understanding of the treatment and disposal processes involved in domestic wastewater treatment has led to poor design and installation of on-site treatment systems, resulting in contamination of groundwater and watercourses. Solid material settles and builds up within the settlement tanks. Sludge from a tank contains a significant number of pathogens and nutrients and so its management is critical to ensure the sludge does not pose a risk to human health and the environment (USEPA, 2000). These problems result mainly from unsuitable natural conditions being encountered at the site like unsuitable soil and subsoil properties for the treatment and disposal of effluent. Domestic effluents contain many substances that are undesirable and potentially harmful to human health and the environment (Tipperary et al., 1998).

Due to an increasing environmental concern regarding the aquaculture wastewater, various methods for treating wastewater have been implemented. Four main stages associated with aquaculture wastewater management are waste collection, fish-fed loss reduction, suspended particle separation, and sludge treatment. The later phase has rarely been considered because of the large increase in sludge volume originating from such sources (Bergheim et al., 1993), however, it is becoming an increasingly significant problem. Filtration is employed in waste treatment wherever suspended solids must be removed. In practice, filtration is most often used to polish wastewater following treatment. In primary waste treatment, filters are often employed to remove oil and suspended solids prior to biological treatment (Gupta and Deshpande, 2004).

2.2 Filtration

Filtration is the process of passing water through material to remove particulate and other impurities, including floc and pollutant from the wastewater being treated (Oszako et al., 2013). These impurities consist of suspended particles (fine silts and clays), biological matter (bacteria, plankton, spores, cysts or other matter) and floc. The material used in filters for public water supply is normally a bed of sand, coal, or other granular substance. Filtration processes can generally be classified as being either slow or rapid (EPA, 1995).

2.2.1 Types of Filter Media

The types of filter beds may be classified according to the structure of the filter media:

a) single medium, fine grain or coarse grain,

b) single medium, decreasing grain size in the direction of the flow,

c) multiple media, bed stratification with decreasing grain size in the direction of the flow.

It is possible to use alternative filter media instead of sand. This can be useful in some areas where sand is not available. Such alternatives include burnt rice hull ash, crushed glass or crushed stone (Table 2.1).

Table 2.1 Alternative filter media (rice hull ash) compared to sand Barnes and Mampitiyarachichi (1983).

Parameter	Rice hull ash medium	Sand medium
Effluent turbidity (NTU)	2.5 – 2.7	5 – 10
Length of filter run (hours)	460	186
Percentage removal of *E. coli*	90-99	60-96

Combustion of rice hulls produces an ash that is 90% silica. As such, rice hull ash has been investigated in Australia as an alternative filter media by Barnes and Mampitiyarachichi (1983). The performance of the rice hull ash was superior to that of the sand with respect to the following parameters when treating water with an influent turbidity of between 40 and 60 NTU. Another study on using crushed glass in place of sand for dual-media rapid sand filters concluded that particle removal capabilities of a crushed glass filter were slightly poorer than those of a sand filter (Rutledge and Gagnon, 2002).

2.2.2 Size of Media

It is very important to select media with correct grain sizes. The grain-size is fundamental to the operation of the filter, affecting the quantity of wastewater that may be filtered, the rate of filtration, the penetration depth of particulate matter and the quality of filter effluent. While, theoretically, grain with a large specific surface area (m^3/m^2) is desired to support the large bacterial populations and too fine a grain limits the quantity of wastewater that may be successfully filtered due to early filter clogging (USEPA, 1985).

For example, by using sand as media, Ellis and Aydin (1995) reported a greater presence of bacteria in a finer sand filter (0.17 mm diameter), than a coarser one (0.45 mm diameter). While coarse sand results in longer filter life but too coarse will lower the retention time resulting in inadequate treatment (Farooq and Al-Yousef, 1993). Filter efficiency does not depend on grain-size alone, however, but also on the degree of sorting, or uniformity coefficient, of the filter sand (Whitehead, 2004).

Each layer of soil with different physical characteristics, such as particle size, color or compactness, should be described separately, and its boundary levels noted. Soils usually are described as gravel, sands, silts or clays, depending on their dominant particle size, in accordance with the following Table 2.2:

Table 2.2 Types and Particle Size of Soil (NDEP, 2008)

Soil types	**Particle Size (mm)**
Gravel	76 - 4.75
Coarse Sand	4.75 - 2.0
Medium Sand	2.0 - 0.425
Fine Sand	0.425 - 0.075
Silt	0.075-0.002
Clay	< 0.002

The size and shape of the filter media affect the efficiency of the solids removal. Sharp, angular media form large voids and remove less fine material than rounded media of equivalent size. The media must be coarse enough to allow solids to penetrate the bed for 2-4 in. Although most suspended solids are trapped at the surface or in the first 1-2 in. of bed depth, some penetration is essential to prevent a rapid increase in pressure drop (Tipperary et al., 1998).

2.3 Sand Filtration

Kristiansen and Cripps (1996) conducted a study on the treatment of wastewater using sand filtration. The objective of their study was to evaluate the feasibility of sand as a renovation, stabilization, and drying system for sludge derived from the first stage treatment of aquaculture wastewater. Feasibility was assessed in terms of hydraulic capacity and treatment efficiency. A large reduction in hydraulic conductivity was caused by the establishment of a clogging mat on the sand filter surface.

Various studies have shown that sand filters attain removal efficiencies of 90% COD, 95% BOD, 30% total nitrogen and 40% total phosphorous (Sauer et al., 1976; Pell et al., 1990; Darby et al., 1996; Van Buuren et. al, 1999). According to the USEPA (1999) sand filters produce a high quality effluent with typical concentrations of 5 mg/L or less of BOD and SS, as well as nitrification of 80% or more of the applied ammonia.

2.3.1 Types of sand filter

There are two main types of sand filters used for water treatment: rapid sand filters (also known as Rapid Gravity Filters or RGFs) and slow sand filters. Sand filters should not be confused with Roughing Filters, which tend to be horizontal-percolation gravel filters used as a roughing treatment for turbid raw waters prior to sand filtration.

The two sand filtration processes differ from each other in several ways. In general however, rapid sand filters are usually fully automated, complex and costly, forming part of a wider treatment process in industrialized countries. They are not known to be suitable for household-level use, as is the case with versions of the slow sand filter, for example the intermittently operated slow sand filter (or IOSFF) (Schulz and Okun, 1984). Phytopathogens removal efficiency through filters depends on their types and activity of microbial processes occurring in their biofilters (Davey and O'toole 2000), which are also affected by anthropogenic pollution.

Another study Wridge et al. (1996) was conducted on intermittent sand filtration for domestic wastewater treatment, focusing on the effects of filter depth and hydraulic parameters. The continuing general need for reliable, cost-effective wastewater treatment in many rural regions, as well as increased land development pressures in environmentally sensitive areas such as shorelines and high relief terrains, are among the forces compelling this renewed interest in intermittent sand filters. Thus, intermittent sand filtration offers a promising and proven technology for low- cost, low-maintenance wastewater treatment.

Biological sand filters have long been used as simple, low-cost means of wastewater management throughout the world (Mancl and Peeples 1991; Tchobanoglous and Burton 1991; Wotton 2002). If properly designed, sand filtration systems can produce high-quality effluent with high bacterial removal efficiencies (Farooq and Al-Yousef, 1993; Stevik et al., 1999; Harrison et al., 2000; Ausland et al., 2002).

2.3.2 Sand size and depth

When using sand as a filter media two important factors play a role; sand grain size and sand bed depth. Both have important effects on bacteriological and physical water quality. Most literature recommends that the effective size of sand used for continually operated slow sand filters (COSSFs) should be in the range of 0.15 – 0.35mm (Schulz and Okun, 1984).

The sand used for a slow sand filters should preferably be rounded, and free from any clay, soil or organic matter. If necessary, the sand must be washed before being used. If the raw water is expected to have high levels of carbon dioxide, then the sand must contain less than 2% of calcium and magnesium, calculated as carbonates. This is to prevent the formation of voids in the media if the calcium and magnesium are removed by solution (Huisman and Wood, 1974).

According to Nam et al., (2000), selection of the correct sand sizes as filter media is essential because of the mechanical filtration mechanisms. A slight increase in treatment efficiency has been observed with decreasing sand size which indicates the importance of straining and adsorption. Higher removals tend to be due to smaller interstices between smaller sand, as well as the larger surface area available of the smaller sand size, which allows more adsorption to take place. In the same way, having sand that is too fine will lead to rapid clogging.

Percolation rate in a sand filter is proportional to the cross-sectional area of the sand, pressure head (hydraulic loading) of water on top of the sand and also the sand characteristics. For example, porosity of sand, which dependent on the type and size of sand in the filter, can both affect the hydraulic conductivity, that is, how much water passes through an area of sand in a particular time.

In coarser sand with a proportionally higher percolation rate, solids in the wastewater are able to penetrate deeper into the sand making cleaning more difficult. A study by Logan et al., (2001) into Cryptosporidium oocyst removal suggested that the larger surface area associated with fine sand as opposed to coarse sand, together with the accompanying increased residence time were more important factors than pore size per se. The higher percolation rates observed in coarser sand lead to poorer bacteriological filtration (Muhammad et al., 1996). This poorer filtration occurs because there is less contact time for biological predation on potential pathogens by the biological layer before the water passes through.

Besides that, a smaller size of sand will have a larger total surface area available for biofilms to grow on, and therefore more biofilm can come into contact with the raw water. This therefore improves treatment effectiveness (Buzunis, 1995). Indeed, a greater combined surface area speeds up chemical reactions (surface catalysis) (Huisman and Wood, 1974).

In addition, percolation rates may cause thinner and sparser biofilms attached to sand grains. Lessons can be learned from a study on biofilms from reactor vessels using 0.60 mm sand size that were found to be thinner and smoother, which was attributed to higher shear environments, in contrast to the thick, rough, porous films measured on 0.23 mm sand samples. While the percolation rates in the study were much higher than slow sand filtration rates, and therefore percolation characteristics will be different, the principles are possibly transferable: percolation rate can affect biofilm development, which in turn can affect filtrate quality (Nam et al., 2000).

In coarser sands, an increased sand bed depth is required as the depth of activity will increase. However an increased bed depth can contribute to better filtration as greater surface area provides a more intimate contact between the constituents of the raw water, thus speeding up chemical reactions (Bellamy et al, 1985).

Interestingly, Ferdausi and Bolkland (2000) found adequate faecal coliform removals to below 10 per 100 mL in pond filters, which only had sand bed depths of around 30 cm. Wridge et al. (1996) stated that filter depth also influenced total suspended solids removal, but to a lesser degree than for BOD removal. The effect of filter depth was also clearly evident for ammonia-N removal. In general, as filter run increased, the filtration rate decreased.

Furthermore, studies have identified the effect of filter media, depth of filter-bed and various variable concentrations such as ammonia, biological oxygen demand (BOD) and nitrate for separating solids and treating wastewater. Therefore; these studies may be helpful in designing an experiment for treating aquaculture sludge with higher percentage of solid (10 – 20%) and wastewater from drum filter at higher moisture content (98.5 to 99.5) (Mishra and Mclean, 2003).

2.3.3 Advantages of Sand Filter

Sand bed filters work by providing the particulate solids with many opportunities to be captured on the surface of a sand grain. As fluid flows through the porous sand along a tortuous route, the particulates come close to sand grains. All types of sand filters achieve high removal rates for sediment, BOD, and fecal coliform bacteria. The filter media is periodically removed from the filter unit, thus also permanently removing trapped contaminants. Waste media from the filters does not appear to be toxic and is environmentally safe for landfill disposal. Finally sand filters also generally require less land than other Best Management Practice (BMP), such as ponds or wetlands (EPA, 1999).

Some research has been done on enhancing the sand media itself to improve the sand's filtration effect. Sands that have been coated with metal oxides and hydroxides improve removal efficiencies of pathogens through enhancing microbial adhesion to sand grains, as well as removal efficiencies of heavy metals (Truesdail et al, 1998). Although the interactions are still poorly understood, they appear to be a result of adsorption mechanisms, such as van der Waals forces and electrostatic interactions (Lukasik et al, 1999).

2.4 Marine worm

Marine worms can be placed into more than ten different phyla and come in a variety of colors, shapes, and sizes. Marine worms are often confused with other animals with thin and long bodies. Marine worms are speciose and numerically prominent members of marine communities where they play critical roles in trophic interactions and in affecting biogeochemical cycles (Kicklighter et al., 2006).

Most marine worms are grouped into the Annelids, a group that includes the Polychaetes (bristle worms), Oligochaetes, Hirudinae, and the *Eunice aphroditois*. Polychaetes are most often found near the shoreline and swim or crawl using a pair of legs found on each segment of their body. Some marine worm species, such as the bearded fire worm, can deliver a nasty burning sting to humans when handled (MarineBio, 2014).

Marine worms live under boulders of rocky ocean shores, among the holdfasts of algae, in mud, sandy mud and in sand, while others build tubes in which to shelter. Marine worms include flatworms, ringed or segmented worms, tube -making worms, burrow-dwelling worms, peanut worms, and ribbon-worms (Davey and O'Toole 2000).

2.4.1 Polychaete

Polychaetes are a group of segmented worms belonging to the phylum Annelida which play an important role in nutrient cycling and in maintaining and sustaining the benthic environment (Henriksen *et al*., 1983; Hutchings, 1998). Certain polychaete worms are highly valued as bait and as aquaculture feeds and are cultured commercially (D'Asaro, 1976; Costa, 1999; Olive, 1999). Nereid worms are valued by the industry as excellent sources of polyunsaturated fatty acids (PUFAs), and they have the potential to supplement fish oil as sources of essential lipid components of feeds (Fidalgo e Costa et al., 2000; Lytle et al., 1990; Olive et al., 2000).

Polychaetes are an ancient group dating back to the Middle Cambrian (540 million years ago), and possibly earlier. However, because they do not fossilise well usually only the jaws, chaetae, tubes and burrows leave imprints - there are large gaps in the fossil record. To date, about 13 000 polychaete species have been described for the world. The actual number of species is estimated to be 25 000 to 30 000 (Mackie et al., 1997).

So, probably there remains over half the actual number of polychaetes to describe. There are presently over 1000 genera, 82 families and 17 higher taxa, which currently have no formal Linnaean rank. Some families and many genera undoubtedly will require revision as the group becomes better known and understood.

2.4.2 *Perinereis nuntia*

A total of 64 species from 31 families of polychaete have been identified throughout Malaysia (Idris and Arshad, 2013). The earliest record of Malaysian (previously Malaya) holotype polychaetes is *Gaudichaudius cimex;* a scaleworm species found in the Straits of Malaca (specific location is unknown) by Quatrefages in 1866 (Solis-Weiss et al., 2004). In addition, holotypes of six species also were collected from Malaysia. The highest number of species identified belong to family Nereididae (nine species), followed by family Capitellidae (five species) and Tomopteridae (four species). *Caobangia abbotti* is currently the only freshwater polychaete species found in Malaysia, and is endemic to Sabah and Sarawak (Jones, 1974).

The *Perinereis nuntia* species is characterized by an arc of bar-shaped paragnaths on Area VI of the eversible proboscis. These Nereididae worms are common in intertidal and shallow marine waters and are widely distributed on the coasts of the' southern continents and the tropical Indo-Pacific. Wilson and Glasby (1993) studied two unidentified species in the *Perinereis nuntia* species group from southeastern Australia and provided guidelines for the interpretation of morphological variability.

Perinereis nuntia group presently comprises of 12 species (Wilson and Glasby 1993). The 7 varieties and subspecies of *Perinereis nuntia* created by Fauvel (1919 1921 1932) and Augener (1913) have either been elevated back to their original species status (e.g., *Perinereis nuntia* var. *vallata* sensu Fauvel, 1932 is now *Perinereis vallata* (Grube, 1858)), or synonymized with other species (Wilson and Glasby 1993).

The polychaete worm, *Perinereis nuntia* is common in sandy beaches around Penang Island, Malaysia. The worms burrow in the sand beneath rocks at the high tide level which is only submerged during extreme high water (Bessie, 1996). Polychaete is a popular aquaculture species among anglers who use it as bait for fishing and also used as feed of prawn broodstock, particularly *Penaeus monodon* (Olive et al., 2002; Costa et al., 2003). The high levels of essential fatty acids in polychaetes can stimulate gonad maturation and spawning in hatcheries fish and prawn broodstocks. In addition to the protein, worms are a valuable source of essential amino acids and vitamins (Davidson et al., 2008).

2.5 Polychaete and Decomposition of Organic Matter

In general, polychaete aids in the decomposition and conversion of organic matter into available nutrients for improved plant productivity, just as earthworms do in horticulture (Palmer, 2008). They may also improve the condition of the farm environment by improving pond bottom soil structures and promoting oxidation of reduced sulphides in sendiments. Opportunities exist for wealth creation through the value of polychaetes. They have high value as bait in the sea angling sport and leisure industry (Gambi et al, 1994; Olive, 1999), but the potential commercial value of polychaetes is not limited to this use.

The ability of a polychaete to decompose organic matter may be applicable to the treatment of organically polluted sediment that accumulates below the fish farms (Chareonpanich et al., 1994). Bivalve molluscs (oysters and clams), polychaete worms, and other invertebrates (amphipods) dominated in the benthic components which complemented fish and seaweeds that were also used as nutrient sinks (Palmer, 2008).

Some recent authors in this area have suggested the use of local species to avoid unnecessary introductions that may result in environmental problems (Costa, 2006; Scaps, 2003). Most of these operations have focused on various species from the family Nereididae, which have proved amenable to intensive culture conditions (*Perinereis nuntia*: Poltana et al., 2007) and have been shown able to synthesize essential fatty acids necessary for the nutrition of marine fish and prawns (Olive, 1999; Costa et al., 2000).

2.6 Application of Polychaete Assisted Sand Filter (PASF) and Vermifilter in Wastewater Treatment

The principle behind PASF lies in the burrowing and feeding activities of the worms in the sand, and their ability to survive and grow on the deposited organic material. They appear to help maintain percolation through the sand filter whilst organic debris that is trapped by the sand directly and becomes their food (Palmer, 2010). Besides that, if worms present on the surface of the filter beds, which was to feed on the organic matter, this can increase the pore size of the medium (keeping the hydraulic conductivity high) and allowing the solids in subsequent liquid sludge applications to be trapped in the filter bed (Mishra & Mclean 2003).

According to Khanobdee et al., (2002) and Laoaroon (2005), the polychaete biomass production levels are sufficiently valuable to fund these low-maintenance water remediation activities on sand bed construction, stocking with polychaete juveniles and polychaete biomass harvest, since the live polychaetes produced are suitable for lucrative bait markets and their proximal and fatty acid analyses suggest they are also valuable for use as marine brood stock conditioning and maturation diets.

There is also a relatively new technology to process organically polluted water using earthworms, which is vermifiltration. It was first advocated by the late Professor Jose Toha at the University of Chile in 1992 (Aguilera, 2003 and Bouché and Qiu, 1998). Vermifiltration of wastewaters is similar to vermiprocessing of solid organics except it is necessary to watch hydraulic loading in addition to organic loading. Vermifilters are self regulated system to discharge uniform quality of effluent. Wastewaters of higher strength of organics either in the form of suspended particles or dissolved solids do not cause problem. Because suspended solids are trapped at the top of the vermifilter, the dissolved solids level may have to be restricted for single pass vermifilter to prevent toxicity. Wastewater below 0.1% dissolved solids need not be diluted and can be directly fed to the single pass vermifilter (Sinha et al., 2008; Pushpangadan et al., 1997).

Earth worms maintain aerobic conditions in the waste mixture, ingest solids, convert a portion of the organic media into biomass and respiration products, and expel the remaining, partially stabilized matter as discrete material (castings). Worms and microorganisms act symbiotically to accelerate and enhance the decomposition of the organic matter. Degradation is a function of the portion of waste that is biodegradable, maintenance of aerobic conditions, and avoidance to toxic conditions. Earthworms perform physical/mechanical and biochemical actions through substrate aeration, mixing, and grinding as they process waste (Mishra, S. and Mclean, E., 2003). A study was conducted by Raymond (1984) for treating municipal sludge (0.3 to 1.6 % total solids) using earthworms and observed that the vermistabilization process reduces approximately 75% TSS and 80% VS at the maximum application rate of 1000 gm VS/m^2/week.

The consistent significant removal of suspended solids from pond waters by sand bed was not surprising given that sand filtration has long been used for this purpose in municipal water treatment (Campos et al., 2002) and various aquaculture applications (Vigneswaran et al., 1999). In practical terms suspended solids are mainly captured in the surface layers of sand filters, and this is where resistance to water infiltration mainly occurs with prolonged use (Palacios and Timmons, 2001).

Total suspended solids (TSS) in effluent can clog the infiltrative surface or soil interstices, reducing the life of the disposal field. A properly functioning septic tank will reduce the TSS in the effluent through sedimentation prior to entry to the disposal system. An effluent filter will further reduce the TSS load to the disposal field (PCLS, 1992). Therefore, it is imperative that the treatment tank be inspected routinely for sludge buildup and pumped regularly to avoid short circuiting of effluent into the disposal system.

Polychaete's survival and production levels in the present study, and demonstrated high values as bait and high quality feed, appear sufficient to drive their economical implementation in the wastewater treatment methods that are documented. Although stocking levels in Palmers study were assumed to be somewhat imprecise, due to the gregarious nature of juveniles in the nursery beds, the numbers recovered from replicate grow-out beds were surprisingly consistent adding confidence to the juvenile enumeration and stocking methods that were applied (Palmer, 2008).