Analysis of aquatic worms in flocculated digested sludge and extraction of extracellular polymeric substances in wastewater treatment plants

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To my beloved family and specially my dears father and mother

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ABSTRACT

Activated sludge process in wastewater treatment plant (WWTP) produces large amount of excess sludge. The disposal of sludge in Netherlands is costly (500 EUR/ton wet solids), and therefore reduction techniques of digested sludge are of great interest to improve the costs of wastewater treatment. First part of this study focused on one of the biological approaches to reduce the excess sludge that can be achieved by aquatic worms in short period of time. Worms are efficient degraders to extra mineralization of sludge into biomass, water and CO_2. In optimal condition the total biomass production is low. The investigation on worm predation shows high concentration of ammonia in sludge is toxic and it inhibits the growth of worms, so flocculation was done to separate ammonia from solid. The hypothesis is that flocculated digested sludge (FDS) can be degraded by aquatic worms. In this study, we evaluated the degradation rate, temperature effect, ammonia concentration and worm growth rate. The obtained results from worm experiment showed, in long test (12 days), with the worm biomass of (21.2 g/ww), the degradation of sludge in worm reactor is (15.75 %), while it is (6.65 %) in aerated reactor. Temperature is not conclusive and it could be between (18 to 22° C). On the second part of the experiment, the extraction of extracellular polymeric substances (EPS) method in flocculated digested sludge to compare with non-flocculated digested sludge was evaluated. The results indicated concentration of EPS in digested sludge and flocculated digested sludge is not the same by applying extraction method named cation exchange resin. Although sonication is an applicable technique to destroy the size of flocs in flocculated digested sludge, the result does not show any balance in amount of extracted EPS in both types of sludge.

ABSTRAK

Proses enapcemar teraktif di loji rawatan air kumbahan (WWTP) menghasilkan jumlah besar kumbahan berlebihan. Pelupusan enapcemar di Belanda adalah mahal (500 EUR / tan pepejal basah), dan oleh itu teknik pengurangan enapcemar dicerna mendapat perhatian yang tinggi untuk meningkatkan kos rawatan air sisa. Bahagian pertama kajian ini memberi tumpuan kepada salah satu pendekatan biologi untuk mengurangkan enapcemar lebihan yang boleh dicapai oleh cacing akuatik dalam tempoh singkat. Worms adalah degraders berkesan untuk mineral tambahan enapcemar ke biomass, air dan CO_2. Dalam keadaan optimum jumlah pengeluaran biomass adalah rendah. Siasatan pada cacing pemangsa menunjukkan kepekatan ammonia yang tinggi dalam enapcemar toksik dan ia menghalang pertumbuhan cacing, jadi pemberbukuan dilakukan untuk memisahkan ammonia daripada pepejal. Hipotesis adalah bahawa flocculated enapcemar dicerna (FDS) boleh dihina oleh cacing akuatik. Dalam kajian ini, kami menilai kadar degradasi, kesan suhu, dan kadar pertumbuhan cacing. Keputusan yang diperolehi dari eksperimen cacing menunjukkan, dalam ujian panjang (12 hari), dengan biomas cacing sebanyak 21.2 g (ww), degradasi enapcemar dalam reaktor cacing adalah 15.75 (%), manakala ia adalah 6.65 (%) dalam reaktor berudara . Suhu tidak boleh dipertikaikan dan ia boleh menjadi antara 18 hingga 22 ̊ C. Kedua sebahagian daripada eksperimen menilai pengekstrakan bahan polimer extracellular (EPS) kaedah dalam enapcemar dicerna flocculated untuk membandingkan dengan bukan flocculated dicerna enapcemar. Hasilnya menunjukkan dengan menggunakan kaedah pengekstrakan kationik resin pertukaran (CER) tidak ada kesetaraan dalam jumlah EPS dalam kedua-dua flocculated kumbahan dan enap cemar bukan flocculated. Walaupun sonication adalah teknik yang diguna pakai untuk memusnahkan saiz flocs dalam enapcemar flocculated, hasilnya tidak menunjukkan apa-apa baki dalam jumlah EPS diekstrak dalam kedua-dua jenis enapcemar

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LIST OF SYMBOLS AND ABBREVIATIONS

WWTPs	-	Wastewater treatment plants
EPSs	-	Extracellular polymeric substances
CER	-	cation exchange resin
GHGs	-	greenhouse gases
TSS	-	total suspended solids
FSS	-	fixed suspended solids
VSS	-	volatile suspended solids
AD		Anaerobic digestion
CO_2		carbon dioxide
WAS		waste activated sludge
LB-EPS		loosely bound EPS
g		Gram
HCHO		Formaldehyde
NaOH		Sodium hydroxide
TS		total solid
VS		volatile solid
L		Litter
NO_3		Nitrate
P		Phosphorus
NaH_2PO_4		Monosodium phosphate
C		Centigrade
UC1		Ultra Check 1
RLU		Relative Light Unit
F-DS		flocculated digested sludge
AD-S		anaerobic digested sludge

EA-FDS	extended aerated flocculated digested sludge
WP-FDS	worm predated flocculated digested sludge
DO	dissolve oxygen
NH4	Ammonium
NH3	ammonia
g/ww	Gera per wet weight
sCOD	Soluble chemical oxygen demand
ATP	Adenosine triphosphate

CHAPTER 1

INTRODUCTION

1.1 Introduction

1.1.1 Sludge Degradation

Wastewater treatment plants (WWTPs) produce large amount of biological waste sludge that composed of water, bacteria, organic and inorganic components such as phosphorus and nitrogen. There are also several pollutants like heavy metals, organic pollutants and pathogen in waste sludge. Amount of pollution in European Union was almost 11 million tons of dry solid at 2005. As it maybe reaches up to 13 million tons till the time 2020 (Kelessidis and Stasinakis, 2012), Some different methods have applied to dispose the waste sludge such as landfills, incineration and application as fertilizer. These treatments are costly and is almost half of the operational price of wastewater treatment (Mailler, et al., 2014). Therefore it is essential to develop some new methods for sludge minimizing (Wei, et al., 2003a).

A biological method to decrease sludge production is utilization of sludge by aquatic worms. Furthermore the worm biomass is grown up by sludge consumption that is a source of protein contents (Elissen, et al., 2010). Sludge minimizing by worm is a usual method in small scale performance especially in developing countries. Worm compost is consumed as a fertilizer due to high amount of nitrogen concentration and less amount of heavy metal composition (Ndegwa and Thompson, 2001). The worm biomass is also applied as compost again or as a component for produce detergents and animal feed (de Boer and Sova, 1998).

1.1.2 Extracellular Polymeric Substances

Extracellular polymeric substances (EPSs), that present outside the cell is secreted by microorganisms in biological system like wastewater treatment plants. It consists of polysaccharides, proteins, uronic acids, humic-like substances, lipids, and DNA. The main characteristic of EPS is its function in metabolism of bacteria and survives them in waste sludge. It is consider as a flocculated agent in wastewater treatment (Sheng, et al., 2010).

The construction of EPS also affects settling and bonding properties of sludge and extends the membrane fouling (Ahmed, et al., 2007). The hydrophobic and hydrophilic regions in EPS structure allow it to attach to heavy metals and organic pollutants. Theses binding affinities consider remarkably to eliminate organic and inorganic pollutants (Pan, et al., 2010; Zhang, et al., 2010).

The main methods to extract EPS are sonication, high speed centrifugation, sonication/centrifugation, heating, alkaline, sulfide, EDTA, CER, and formaldehyde/NaOH treatment (Liu and Fang, 2003).

The amount of EPS extraction depends on type of extraction method. The extraction methods also affect the recovery rates and the fluorescence characteristics of EPS. CER and formaldehyde/NaOH are the most popular methods (Sheng, et al., 2005).

This research focused on two aspects: the first one was the consumption of flocculated digested sludge by worm. It explained how compact sludge was eaten by worm at different times. Studies on oligochaete predation showed that large reduction in flocculated digested sludge volume was achieved in a relatively short amount of time. It also indicated predation could increase the overall biodegradability of sludge when paired with anaerobic digestion. Visual characteristics of worm were observed under microscope to understand which species was more strength to digest flocculated sludge.

Second aspect was the extraction of extracellular polymeric substances (EPSs) by cation exchange resin (CER) method in anaerobic digested sludge and flocculated digested sludge. The emphasis was on improvement of EPS extraction method in flocculated digested sludge to achieve the same amount of EPS in both types of sludge. In this case sonication was applied to reduce the size of flocs in point of more extraction.

1.2 Problem Statement

The high growth of industrialization and urbanization are the main causes of large amount of pollution from wastewater treatment plants (WWTPs). Destroying of sludge is always the main concern in wastewater treatment because it contains almost more than half of price in total plant and the rules regarding sludge removal are being significantly stringent (Pilli, et al., 2011).

Principal techniques for sludge removal are landfill, land application and incineration. Land application is limited to stop health dangers to human being and animals because of probably poisonous components in the sewage sludge, such as heavy metals, pathogens, and strong organic contaminants. Decrease of available land area, along with growing strict rules governing the pattern of innovative landfills, construction, and operating new landfills have increased greatly. Commonly, incineration is usually the last alternative for sewage sludge disposal. The method produces ash, which often runs into landfill since it is unable to dispose somewhere else because of large amount of heavy metals and overall toxicity. Therefore, the existing legal limitations, the growing costs and public awareness of sewage sludge disposal have supplied significant fame to develop technologies for minimization of sludge generation (Wei, et al., 2003b).

To solve these problems some new techniques were utilized specifically in the activated sludge process. Several suggested strategies depend on decreasing sludge generation by growing the total sludge age. Some other methods are generally based on hydrolysis enhancement rate and also increase of biodegradability. Applied methods consist of mechanical, chemical, thermal and biological processes and might be located as pre-treatment step. The disadvantage of many of these types of methods is which they are actually energy and cost demanding. Due to environmental and economical limitations, there is a desire for cost-effective and ecological technologies for sludge treatment. The majority of suggested strategies are not relying on cycling of organic carbon in environment. Complicated organic carbon in environment is usually converted by higher organisms such as benthic earthworms and it seems a reasonable way to integrate worms into a process of sludge digestion in wastewater treatment plant (Tamis, et al., 2011).

As large amount of activated sludge are produced in wastewater treatment plant, dewatering is great interest to decrease the volume of sludge and manage the properties improvement. Organic polymer is broadly used more than other chemicals in wastewater industry.

Therefore the specific study of EPS is certainly an interesting subject not only in case of improving our information about biological wastewater treatment, but also enhancing the effectiveness of treatment by optimization of functional parameters.
Due to the necessity of EPS in flocs configuration and stability, a wide range of researches have tried to extract and evaluate EPS from activated sludge ,so a number of extraction methods have been applied for this reason.

1.3 Objectives

The aims of the study are:

- To analyse the aquatic worms in flocculated digested sludge
- To analyse extraction of extracellular polymeric substances in flocculated digested sludge and anaerobic digested sludge

1.4 Significance of the Study

The use of biological methods in wastewater treatment has received a lot of attention nowadays due to low cost and high efficiency. This study will aid to reduce the amount of flocculated digested sludge in wastewater by using worms as predators. Furthermore, the worms were applied in this study have previously been screened to degrade activated sludge and that result is promising to pursue the experiment for flocculated sludge. The worm predation process has been shown to be affected by ammonia concentration, so it has to remove during experiment. The worms are able to survive easily in lab environment. Consequently it can be an economical treatment.

Cation exchange resin is a chemical method to extract extracellular polymeric substances. This study will assist to get the same amount of EPS in both flocculated digested sludge and anaerobic digested sludge by CER method.

1.5 Scope of Study

The potential of aquatic worms to degrade flocculated digested sludge in wastewater treatment plant by measuring total solid and volatile solid. The amount of ammonia, total nitrogen, phosphorus, COD, dissolved oxygen, pH, and temperature were examined during experiments. Also the physical features of worms were observed under microscope to find which types of worm can survive during the experiment.

Beside that the EPS was extracted by CER method in flocculated digested sludge and anaerobic digested sludge. Sonication was applied for flocculated digested sludge to get the same output for both types of sludge.

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