UNIVERSITI PUTRA MALAYSIA

STABILIZATION OF THICKENED-ACTIVATED SLUDGE THROUGH THE ANOXIC-AEROBIC DIGESTION PROCESS

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Thesis Submitted to the School of Graduate Studies, University Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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DEDICATION

Especially dedicated to my dearest:

Father, mother, sister Leng and sister Shian.

Will never ever let you down!

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Aerobic digestion is widely used to treat waste-activated sludge and thickened sludge from wastewater treatment plant due to its shorter retention time and achieving the same efficiency in solids volume reduction compared to anaerobic digestion. However, the supernatant and filtrate from the aerobic digestion system contain high concentration of suspended solids. The nitrogen which had been embedded in sludge is solubilized to form ammonical and nitric nitrogen which in turn transferred to the liquor and cause the increase of nitrogen loading in sewage treatment plant. In this study, anoxic-aerobic digestion is applied to remove both the mixed-liquor volatile suspended solids (MLVSS) and soluble nitrogen simultaneously. The objectives of the study are to investigate and evaluate the removal efficiency of both MLVSS and soluble nitrogen by anoxic-aerobic digestion and compared to the aerobic control digesters, with and without lime control.

By applying anoxic-aerobic digestion, a comparable of MLVSS reduction was gained to aerobic digestion. 66.12% and 63.00% of MLVSS destruction was found in both anoxic-aerobic digesters, with and without methanol addition respectively.

Aerobic with lime control tended to have the greatest solids reduction, which was 66.30%. Percent MLVSS reduction in aerobic control digester was 60.76%, the lowest among the digester. There was no unfavorable condition in anoxic-aerobic digesters due to the well maintenance of alkalinity and mixed-liquor pH levels naturally. The endogenous decay coefficients were found 0.0581 day^{-1} and 0.0548 day^{-1} in anoxic-aerobic digester with and without methanol addition respectively, similar rate with lime control digester of 0.0584 day^{-1} in decay coefficient.

Nitrate generated ***in situ*** due to nitrification was utilized through endogenous nitrate respiration (ENR) during the anoxic periods. Thus, reduced nitrates levels in the supernatant in anoxic-aerobic digesters. In this study, it showed that anoxic-aerobic digestion yielded comparable percent solids reduction, despite less energy consumption. It maintained neutral mixed-liquor pH levels without any chemical or lime control. In addition, significant removal of soluble nitrogen and reduced in phosphorus released were realized.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENSTABILAN ENAP-CEMAR TERPEKAT MELALUI PROSES PENCERNAAN ANOXIC-AEROBIK

Oleh

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Pencernaan aerobik digunakan secara meluas untuk merawat enap-cemar teraktif dan enap-cemar terpekat daripada loji rawatan air-sisa disebabkan masa penahanannya yang lebih pendek serta pencapaian keberkesanan yang setara dalam pengurangan isipadu pepejal jika berbanding dengan pencernaan anaerobic. Walaubagaimanapun, bendalir dan hasil turasan daripada pencernaan aerobik mengandungi kepekatan pepejal terampai yang tinggi. Nitrogen yang terkandung dalam pepejal ini terlarut dan membentuk ammonical dan nitrik nitrogen, lantaran mempertingkatkan kandungan nitrogen dalam loji rawatan sisa kumbahan. Dalam kajian ini, anoxic-aerobik digunakan untuk menyingkir pepejal terampai termeruap (MLVSS) and nitrogen terlarut. Tujuan kajian adalah mengkaji dan keberkesanan penyingkiran kedua-dua MLVSS dan nitrogen terlarut secara anoxic-aerobik, berbanding dengan pencerna aerobik, dengan dan tanpa kawalan kalsium hidroksida, sebagai pencerna kawalan

Pengurangan dalam MLVSS yang setara diperoleh dengan menggunakan percernaan anoxic-aerobik. Pengurangan MLVSS sebanyak 66.12% and 63.00%

diperoleh dalam kedua-dua pencerna anoxic-aerobik, dengan dan tanpa penambahan metanol masing-masing. Aerobik dengan kawalan kalsium hidroksida mencatat pengurangan pepejal yang terbanyak, iaitu 66.30%. Peratus pengurangan MLVSS dalam pencerna kawalan aerobik ialah 60.76%, terendah antara kesemua pencerna. Tiada kelampauan keadaan dalam pencerna-pencerna anoxic-aerobik kerana alkaliniti dan tahap pH dimantapkan secara semulajadi sepanjang kajian. Pemalar pereputan endogenous ialah 0.0581/hari dan 0.0548/hari dalam pencerna anoxic-aerobik, dengan dan tanpa tambahan metanol masing-masing. Kadar adalah lebih kurang setara dengan pencerna kawalan pH , iaitu 0.0548/hari pemalar pereputannya.

Nitrate yang dihasilkan semasa nitrifikasi digunakan dalam proses respirasi nitrate endogenous (ENR) semasa waktu   Ini mengurangkan aras nitrate dalam supernatant. Dalam kajian ini, ia menunjukkan pencernaan anoxic-aerobik mendatangkan peratusan pengurangan pepejal yang setara , malahan penggunaan tenaga yang lebih kurang. Ia memelihara tahap pH neutral tanpa sebarang tambahan bahan kimia atau kawalan kalsium hidroksida. Tambahan pula, penyingkiran nitrogen yang ketara dengan pengurangan pembebasan fosforus juga dapat diperhatikan.

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I wish to extend my appreciation to my course mates, for being so kind in helping me in all the ways they could to complete this study. Lastly, thanks to my family members as well, for their encouragement and supports.

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledge. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

Tan Ming Ying

Date:

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LIST OF ABBREVIATIONS

BNR	Biological Nutrient Removal
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
ENR	Endogenous Nitrate Respiration
k_d	Endogenous Decay Coefficient
k_n	Nitrogen Removal Rate Coefficient
MLpH	Mixed-liquor pH
MLSS	Mixed-liquor Suspended Solids
MLVSS	Mixed-liquor Suspended Volatile Solids
Q_s	Influent Flow rate
S_o	Initial Sludge Concentration
S	Sludge Concentration
S_r	VSS concentration Reduced
SRT	Solids Retention Time
SS	Suspended Solids
TS	Total Solids
V	Digester Volume
TVSS	Total Volatile Suspended Solids
VSS	Volatile Suspended Solids

CHAPTER I

INTRODUCTION

Increasing amount of sludge has become a main problem in wastewater treatment plant. Sludge consists of primary sludge, activated sludge, thickened sludge and sewage sludge. It is estimated that more than 65% of treatment operating cost are spent in the sludge stabilization and disposal process. Sludges are stabilized to (1) reduce pathogens, (2) eliminate offensive odors, and (3) inhibite reduce, or eliminate the potential for putrefaction. Therefore, it is important to establish and come out a more suitable protocol to deal with the sludge to reduce the total mass of sludge (volatile suspended solids).

Aerobic digestion is widely used to treat waste-activated sludge discharged from a biological wastewater treatment process. Aerobic digestion is the digestion of sludge that occurs in the presence of oxygen. Aerobic digestion is an alternative method of treating the organic sludges produced from various treatment operations. It has been reported that aerobic digestion has a number of advantages. Advantages associated with aerobic digestion when compared to anaerobic digestion, citing improved supernatant quality, formation of stable and-products, and equal volatile solids reduction for secondary sludge. However, a disadvantage is the higher energy cost associated with aerobic digestion, due to aeration requirements. Although the retention time of aerobic digestion is shorter than that of anaerobic digestion, it can achieve the same efficiency in the reduction of sludge volume as that of the anaerobic digestion. Furthermore, it produces an odorless ands table sludge. This aerobically digested sludge can be used for land reclamation and as fertilizer for agricultural purposes with or without dehydration.

However the supernatant and the filtrate from the aerobic digestion system has been reported as a strong polluting agents because they still contain a high concentration of suspended solids, such as organic materials and nutrient salts. This is aggravated particularly by the fact that during the process of aerobic digestion, the nitrogen, which had been embedded in the activated sludge, is solubilized to form ammoniacal and nitric nitrogen, which are in turn transferred to the liquor. When both the supernatant and filtrate are returned to the top of the treatment plant and are mixed with the influent, the plant will be loaded higher than usual.

It was reported that the return of both supernatant and filtrate from various sludge treatment facilities the top of the treatment plant affected significantly the loading rate of wastewater treatment process. In effect, the total nitrogen content of the liquor becomes very high. Unfortunately, the nitrogen content of the liquor can not be efficiently removed by the digestion process. When the nitrogen concentration of the influent is increase, the overall total nitrogen removal efficiency if the system is subsequently lowered. When an effluent which contains high nitrogen concentration is discharged to waterways such as rivers, lakes, and seas, it includes artificial eutrophication, promoting the growth of red tide, water bloom, even if the biological oxygen demand is very low,

Susumu *et al* (1982) had conducted experimental works of the applicability of the anoxic-aerobic high sludge concentration activated sludge process in reducing both the volatile suspended solids and the total nitrogen content simultaneously. The concept of anoxic-aerobic sludge digestion incorparates, at regular intervals, non-aerated periods during aerobic digestion. This produces a digester, which cycles between anoxic and aerobic conditions. The cycling of the air would have at least two benefits: (1) less air consumption and (2) maintenance of a neutral pH as a result of alkalinity consumption and production by way of nitrification-denitrification processes.

In this study, the experiment was carried out to reduce the volatile suspended solids and suspended solids (total mass of sludge) and nitrogen concentration in supernatant by adapting the anoxic-aerobic digestion system.

Objectives

1. To observe the solids destruction and soluble nutrients removal through the anoxic-aerobic system

2. To assess the acceptability of anoxic-aerobic digestion, in comparison to fully aerobic digestion, with or without pH control.

CHAPTER II

LITERATURE REVIEW

Sludge, Thickening and Stabilization

Activated sludge generally has a brown, flocculant appearance. If the colour is dark, the sludge may approaching a septic condition. If the colour is lighter than usual, there may be have been underaeration with a tendency for the solids to settle slowly (Metcalf and Eddy, 1991). Sludge in good condition has an inoffensive "earthy" odor. The sludge tends to become septic rapidly and then has a disagreeable odor of putrefaction. Activated-sludge will digest readily alone or when mixed with primary sludge. Comparable to activated sludge, primary sludge is from primary settling tanks with gray and slimy and in most cases, has an extremely offensive odor. Primary sludge can be readily digested under suitable condition of operation (Bruce, 1984). Sludge can be either digested through aerobic digestion or anaerobic digestion. Table 2.1 shows the typical chemical composition and properties of untreated sludge, digestion sludge and activated sludge.

Thickening is a procedure used to increase the solids contents of sludge by removing a portion of the liquid fraction before the sludge proceeds any stabilization and conditioning process (. Waste activated sludge from the sewage treatment typically pumped from secondary settling tanks with a content of 0.8 to 2.5 percent solids, can be thickened to a content of 4 percent solids, then a five-fold decrease in sludge volume is achieved. Thickening is generally accomplished by physical means, including gravity settling, flotation, centrifugation, and gravity belt.

Table 2.1: Typical Chemical Composition and Properties of Untreated, Digested Primary Sludge and Activated Sludge

Item	Untreated primary sludge		Digested primary sludge		Activated sludge
	Range	Typical	Range	Typical	Range
Total dry solids (TS), %	20 – 30	5.0	6.0 – 12.0	10.0	0.83 – 2.16
Volatile solids (% of TS)	60 – 80	65	30 –60	40	59 – 88
Grease and fats (% of TS)					
1. ether soluble	6 – 30	-	5 –20	18	-
2. ether extract	7 – 35	-	-	-	5 – 12
Protein (% of TS)	20 – 30	25	15 –20	18	32 – 41
Nitrogen (N, % of TS)	1.5 – 4.0	2.5	1.6 – 6.0	3.0	24 – 5.0
Phosphorus (P_2O_5,% of TS)	0.8 –2.8	1.6	1.5 – 4.0	2.5	2.8 – 11.0
pH	5.0 – 8.0	6.0	6.5 – 7.5	7.0	6.5 – 8.0
Alkalinity (mg/L as $CaCO_3$)	500 – 1500	600	2500 – 3500	3000	580 – 1100
Organic acids (mg/L as Hac)	200 - 2000	500	100 – 600	200	1110 - 1700

(Source: Metcalf and Eddy, Inc,. 1991. Wastewater Engineering: Treatment, Disposal and Reuse, 3rd Ed., McGraw-Hill Publishing, Toronto, pp 765-926.)

The volume reduction obtained by sludge concentration is beneficial to subsequent treatment process such as digestion. Therefore during digestion, the capacity of digesters and equipment can be reduced, and amount of chemical required for sludge conditioning is in lesser quantity.

A reduction in sludge volume may result in a reduction of pipe size and minimum velocity may necessitate the pumping of significant volumes of wastewater in addition to sludge. Gravity thickening is accomplished in a tank similar in design to a conventional sedimentation tank. Normally a circular or a rectangular tank is used. Dilute sludge is fed into the tank and allowed to settle and compact. The thickened-sludge is withdrawn from the bottom of the tank and the effluent is collected and readily discharged into the waterway. The thickened-sludge that collected from the bottom of the tank is pumped to the dewatering equipment or digesters as required. Table 2.2 shows the occurrence of thickening methods in sludge processing.

Aerobically digested sludge is brown to dark brown and has a flocculant appearance. The odor if aerobically digested sludge is not offensive, it is often characterized as musty. Well-digested aerobic sludge dewater easily on drying beds. Anaerobically digested sludge is dark brown to black and contains an exceptionally large quantity of gas. When thoroughly digested, it is not offensive, its odor being relatively faint and like that if hot tar, burnt rubber or sealing wax.

Table 2.2: Occurrence of Thickening Methods in Sludge Processing

Method	Type of sludge	Frequency of use and relative success
Gravity	Untreated primary	Commonly used with excellent results. Sometimes used with hydroclone degritting of sludge.
Gravity	Untreated primary and waste activated sludge	Often used. For small plants, generally satisfactory results with sludge concentrations in the range of 4 to 6 %. For large plants, results are marginal.
Gravity	Waste activated sludge	Seldom used. Poor solids concentration (2 to 3%)
Dissolved-air flotation	Untreated primary sludge and waste activated sludge	Some limited sue; results similar to gravity thickeners.
Dissolved-air flotation	Waste activated sludge	Commonly used; good results (3.5 to 5.0% solids concentration)
Imperforate basket centrifuge	Waste activated sludge	Limited use; excellent results (8 to 10% solids concentration)
Solid bowl centrifuge	Waste activated sludge	Increasing; good results (4 to 6% solids concentration)
Gravity belt & rotary drum thickener	Waste activated sludge	Increasing; good results (3 to 6% and 5 to 8% solids concentration respectively)

(Source: Metcalf and Eddy, Inc,. 1991. Wastewater Engineering: Treatment, Disposal and Reuse, 3rd Ed., McGraw-Hill Publishing, Toronto, ON., 765-926.)

When drawn off onto porous beds in thin layer, the solids first are carried to the surface by the entrained gases, leaving a sheet of comparatively clear water. The water drains off rapidly and allows the solids to sink down slowly on the bed. As the sludge dries, the gases escape, leaving a well-cracked surface with an odor resembling that of garden loam.

Generally, sludge processing includes the steps of preliminary operations, thickening, stabilization, conditioning, disinfection, dewatering, drying, composting, thermal reduction and ultimate disposal. Sludges are stabilized to (1) reduce pathogens, (2) eliminate offensive odors, and (3) inhibite reduce, or eliminate the potential for putrefaction. The success in achieving these objectives is related to the effects of stabilization operation or process on the volatile or organic fraction of the sludge. Survival of pathogens, release of odors, and the putrefaction occur when microorganisms are allowed to flourish in the organic fraction of the sludge. The means to eliminate these nuisance conditions through stabilization are (1) the biological reduction of volatile content, (2) the chemical oxidation of volatile matter, (3) the addition of chemicals to the sludge to render it unsuitable for the survival of microorganisms, and (4) the application of heat to disinfect or sterilize the sludge. .

The technologies that applicable for sludge digestion are (1) lime stabilization, (2) heat treatment, (3) anaerobic digestion and (4) aerobic digestion. The method, which is more favourable in this study is anoxic-aerobic.

It is important to consider the sludge quantity to be treated, the integration of the stabilization process with other sludge quantity to be treated, the integration of the stabilization process with the other treatment units, and the objectives of the stabilization process. The objectives of the stabilization process are often affected by the existing or pending regulations (Bruce and Fisher, 1984). If the sludge is to be applied on land, pathogen reduction by various of sludges stabilization has to be considered.

Aerobic Digestion

Aerobic digestion is ideally suited to the treatment of most waste-activated sludge, especially in small plants. Carried out in a separate reactor, aerobic digestion relies on extended aeration to produce a biological stable end-product suitable for disposal or subsequent treatment in a variety of process.

Adams and Eckenfelder (1981) summarized that the advantages claimed for aerobic digestions as compared to anaerobic digestion, citing improved supernatant quality, formation of stable end-product, and equal volatile solids reduction for secondary sludges. However, a disadvantage is the higher energy costs associated with aerobic digestion due to aeration requirements. The advantages of aerobic digestion are as follows:

1. Volatile solids reduction is approximately equal to that obtained anaerobically
2. Lower BOD concentrations in supernatant liquor
3. Production of an odorless , humus-like, biological stable end product
4. Recovery of more of the basic fertilizer values in the sludge
5. Operation is relatively easy