UNIVERSITI PUTRA MALAYSIA

DRYING KINETICS AND STABILISATION OF SLUDGE IN SLUDGE LAGOON

ONG BEE YEN

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By

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Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Science in Faculty of Engineering Universiti Putra Malaysia

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Dedicated To:

My dearest and beloved parents, brothers, sisters

and Theng for their loving care

and endless encouragement

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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Chairman: Associate Professor Dr. Azni Bin Haji Idris

Faculty: Engineering

Sludge lagoon is a simple and cost effective method for sludge dewatering, especially in countries where land is available and relatively inexpensive, and the evaporation rate is higher than the precipitation rate. Immediate or short term solution is required to solve the problem of high sludge production rate in the country. Sludge lagoon holds privileges as various treatment processes can occur simultaneously in the lagoon, which include thickening, dewatering, storage and stabilisation. Two types of sludge lagoons with different initial sludge depth (0.750m and 0.375m) were investigated for the drying behaviour and drying efficiency. The first design is sludge lagoon with clay bottom where the dewatering mechanisms are decanting supernatant and evaporation. The second design is sludge lagoon installed with sand and underdrains system, where the dewatering mechanisms are filtration or draining and evaporation.

Septic tank sludge was used in this study and the experiment was carried out under transparent roof to avoid raining effects. Sludge drying kinetics models with high

fitness (as shown by regression factor, R^2 higher than 0.90) had been developed to describe sludge drying behaviour. Drying of sludge in sludge lagoon with clay bottom can be best described by exponential function, whereas, drying of sludge in sludge lagoon with sand and underdrains system followed logarithmic function.

The results of the study show that sludge lagoon with sand and underdrains system and shallower sludge depth had highest drying efficiency. Decanting supernatant can remove most of the free water, whereas draining or filtration mechanism can remove all the free water and part of the interstitial (capillary) water. Highest sludge drying rate had contributed towards highest sludge compaction rate. As the drying process proceeded, total solids content and nitrate content were increased, whereas pH value and ammonium content were reduced.

The reduction in volatile solids was lower than 4 percent for all sludge lagoons during the study period. Sludge lagoon with highest drying efficiency was associated with highest reduction in fecal coliform density. Generally, concentrations of heavy metals detected in the final sludge were below the acceptable USEPA limits for land application of clean sludge except for lead. Final sludge contained high percentage of primary nutrient values where the possibility for beneficial reuse as soil conditioner should be investigated.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
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KINETIK PENGERINGAN DAN PENSTABILAN ENAPCEMAR DALAM KOLAM ENAPCEMAR

Oleh

ONG BEE YEN

Julai 2001

Pengerusi: **Profesor Madya Dr. Azni Bin Haji Idris**

Fakulti: **Kejuruteraan**

Kolam enapcemar merupakan satu cara pengeringan enapcemar yang mudah dan kos-efektif, terutamanya di negara yang mempunyai tanah yang mudah diperolehi dan murah, serta kadar penyejatan melebihi kadar hujan. Penyelesaian secara serta merta atau jangka pendek amat diperlukan untuk menangani masalah kadar penghasilan enapcemar yang tinggi. Kolam enapcemar mempunyai kelebihan di mana pelbagai proses boleh berlaku serentak di dalam kolam, ini termasuk pemekatan, pengeringan, penyimpanan dan penstabilan. Dua jenis kolam enapcemar dengan kedalaman enapcemar yang berlainan (0.750m dan 0.375m) dikaji untuk memerhatikan tingkah laku dan keberkesanan pengeringan. Rekabentuk kolam enapcemar yang pertama ialah dengan tanah liat sebagai lapisan dasarnya, di mana mekanisma pengeringan adalah melalui penuangan cecair jernih di atas lapisan enapcemar dan penyejatan. Rekabentuk kolam enapcemar yang kedua ialah dengan lapisan pasir dan sistem saliran bawah, di mana mekanisma pengeringan adalah melalui penurasan atau pengaliran dan penyejatan

Enapcemar tangki septik digunakan dalam kajian ini dan kajian dilakukan di bawah bumbung lutsinar supaya kesan hujan dapat dielakkan. Model kinetik pengeringan enapcemar dengan ketepatan yang tinggi (ditunjuk oleh faktor regresi, R^2 yang lebih daripada 0.90) telah diperolehi untuk menjelaskan tingkah laku pengeringan enapcemar. Pengeringan enapcemar dengan dasar tanah liat didapati paling tepat diterangkan dengan fungsi eksponen. Manakala, pengeringan enapcemar dengan dasar pasir dan sistem saliran bawah paling tepat diwakili dengan fungsi logaritma.

Keputusan kajian menunjukkan bahawa kolam enapcemar dengan dasar pasir dan saliran bawah, serta kedalaman yang cetek mempunyai keberkesanan pengeringan yang tinggi. Penuangan cecair jernih atas lapisan enapcemar berupaya membuangkan kebanyakan 'air bebas', manakala penurasan berupaya membuangkan kesemua 'air bebas' dan sebahagian daripada 'air kapilari'. Kadar pengeringan enapcemar yang tinggi menyumbang kepada kadar mampatan enapcemar yang tinggi. Apabila proses pengeringan berlanjutan, jumlah pepejal dan nitrat bertambah, manakala nilai pH dan ammonium berkurang.

Pengurangan dalam pepejal meruap didapati kurang daripada 4 peratus untuk semua kolam enapcemar dalam kajian ini. Kolam enapcemar dengan kadar keberkesanan pengeringan yang tinggi juga mancapai pengurangan ketumpatan fekal koliform yang tinggi. Secara umumnya, kandungan logam berat dalam enapcemar akhir adalah di bawah had USEPA untuk aplikasi tanah dengan enapcemar bersih kecuali logam plumbum. Enapcemar akhir masih mengandungi nutrien utama pada nilai yang tinggi di mana kemungkinan faedah guna semula sebagai penyubur tanah harus dikaji.

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LIST OF ABBREVIATIONS

C0.75	Sludge lagoon with clay bottom and sludge depth of 0.750m (first run)
C0.37	Sludge lagoon with clay bottom and sludge depth of 0.375m (first run)
S0.75	Sludge lagoon with sand and underdrains system and sludge depth of 0.750m (first run)
S0.37	Sludge lagoon with sand and underdrains system and sludge depth of 0.375m (first run)
C0.75*	Sludge lagoon with clay bottom and sludge depth of 0.750m (second run)
S0.75*	Sludge lagoon with sand and underdrains system and sludge depth of 0.750m (second run)

CHAPTER 1

INTRODUCTION

1.1 General

Sewage includes human waste, urine and wastewater from kitchen, bathrooms and laundries are generated daily by human activities. Untreated sewage may pollute the river and carry infectious pathogenic organisms into river, causes spread of diseases like cholera, typhoid and hepatitis A (Indah Water Konsortium Sdn. Bhd., 2000). To safeguard the public health and ensure cleanliness of the country, sewage must be treated and disposed of in a safe manner.

Sewerage system plays the roles to collect, transfer, treat and dispose of human waste and wastewater in the country. In certain countries the sewerage systems are designed to treat commercial and industrial wastewater including sewage, however Malaysia's sewerage system treats only human waste and household wastewater (Indah Water Konsortium Sdn. Bhd., 2000).

All the wastewater treatment system from individual septic tanks to the most sophisticated mechanical plants produce sludge. Sewage sludge is the solid removed from wastewater originates from households and industrial activity during sewage treatment (Try and Price, 1995). It is mainly comprised of water (97 percent) and trace amount of suspended and dissolved organic and inorganic solids. The primary nuisance of sewage sludge to the public health and environment were identified as odour, heavy metal and pathogen. Therefore, sewage sludge treatments will always include the reduction of organic matter, heavy metal, pathogenic organism and odour problem (Bruce et al., 1984).

According to Indah Water Konsortium Sdn. Bhd. (2000), Malaysia produces approximately 5 million cubic meters of domestic sludge annually and this figure is expected to rise to 7 million cubic meters per year by the year 2022. Immediate solution to sludge problem is to use existing sewage treatment plants with excess capacity to treat septic tank sludge. Another short terms (2 to 5 years) solution is to construct sludge lagoons, which will serve as sludge holding and treatment facilities (dewatering and stabilisation). However, sludge digestion and mechanical dewatering facilities are needed for long term use in urban areas.

One of the main objectives of sludge treatment is to reduce the water content. The advantages of dewatering are two folds. First, it reduces the sludge volume, which subsequently cut down the handling and transportation cost and, secondly it can improve the physical properties of the sludge making it easier to handle (Lester, 1990).

There are various methods to dewater sludges, which range from conventional air drying of sludge on open air drying beds to mechanical systems such as filter presses and centrifuges (Outwater, 1994). The selection of a treatment method considering not only the achievable effluent or final solids qualities, it also involves economic factor. Sludge lagoon is relatively cheep and easy to construct compare to mechanical dewatering facilities. According to Outwater (1994), sludge lagoon is a simple and cost effective method of dewatering sludge if the climate is hot and dry, land is available and inexpensive, and there are no neighbours or odour insensitive neighbours nearby.

Sludge lagoon is similar in concept to a deep sand drying bed with restricted drainage. Lagoons are generally built by enclosure of a land area with dikes or berms, or by excavation, with no attempt to maximise drainage with the underdrains or by a sand layer. However, it is usually desirable for lagoons to have good drainage (Williams and Culp, 1986). Sludge lagooning offers some privileges compare to conventional sand drying bed as it allows stabilisation or biodegradation process to take place in addition to thickening and dewatering prosesses (Indah Water Operations Sdn. Bhd., 1997).

This study focuses on determining design parameters involving sludge lagoon that is intended for drying and dewatering of stable sewage sludge.

1.2 Scope of the Study

This study explored the physical and biological treatment processes occurred in simulated sludge lagoons. The raw material used in this study was sludge from septic tank. The physical processes studied include dewatering by decanting supernatant and draining of filtrate, drying by evaporation and compaction of sludge. Whereas the biological processes studied include the biodegradation of sludge and changes of fecal-coliform density during storage, digestion and drying of sludge. As most of the previous studies on sludge lagoon focus on sludge dewatering and drying aspect, hence the biodegradation and stabilisation of sludge likely to occur in sludge lagoon is not well-understood especially in hot tropical climate like Malaysia.

The changes of organic matters, nitrogen content, phosphorus, pH, and heavy metals were monitored to give an illustration of the processes occur in sludge lagoons. Biodegradations of organic matter were studied by using volatile solids as indicator.

1.3 Significance of the Study

Sludge lagoon is a quite old method used for handling of wastewater treatment plant sludge. Countries with hot and arid climates, which receive evaporation rates higher than precipitation rates especially favour sludge dewatering using sludge lagoon. In Malaysia, conventional sand drying bed is most commonly employed for sludge dewatering. However, recently the concept of sludge lagoon is re-introduced to seek for the opportunity for further digestion or stabilisation to take part in the lagoon and simultaneously dewater and holding the large volume of sludge generated in the country. It is also believed that sludge lagoon with clay lining at the bottom can prevent groundwater contamination compare to conventional sand drying bed.

Since sludge lagoon has significant importance in solving sludge problem for the country. Hence, it is of great interest to know the feasibility and performance of sludge lagoon under Malaysia condition, before full-scale lagoon can be constructed and put into operation. Most of the recent studies on sludge dewatering available in literature reviews focus on mechanical dewatering system and the dewatering data on sludge lagoon are insufficient. Data on biodegradation of sludge, changes of fecal coliform density, nutrient and heavy metals in sludge lagoon are even unknown. Therefore, this study was carried out to generate all these raw data for understanding the processes occur in sludge lagoon and the achievable quality of dried sludge for land application or other uses. The data can also provide information for operator and decision maker for the operation and design or modification of the sludge lagoon under Malaysia conditions.

1.4 Objectives of the Study

Generally, this study aims to investigate the sludge dewatering, drying and stabilisation processes involve in lab-scale simulated sludge lagoons and to know the feasibility of dewatering and treatment of sludge using sludge lagoon under Malaysia condition. More specifically, objectives of this study can be summarised as follows:

1. To analyse the dewatering characteristics of sewage sludge.
2. To study sludge dewatering and drying kinetics in sludge lagoon with different design configurations (system with clay lining and system with sand filter media/underdrains) and different sludge depths (0.750m and 0.375m).
3. To investigate the degree of biodegradation and stabilisation of sludge in sludge lagoon, in the aspects of reduction of volatile solids and fecal-coliform density.
4. To determine the quality of final solid from sludge lagoon in terms of nutrient values, heavy metals and fecal-coliform density.