UNIVERSITI PUTRA MALAYSIA

SEWAGE SLUDGE INCINERATION: GAS EMISSIONS AND HEAVY METALS STUDIES

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

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قَالُوا۟ سُبْحَٰنَكَ لَا عِلْمَ لَنَآ إِلَّا مَا عَلَّمْتَنَآ ۖ إِنَّكَ أَنتَ ٱلْعَلِيمُ ٱلْحَكِيمُ ﴿٣٢﴾

Surat Al-Baqara.

To my parents, brothers and sisters

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

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December 1999

Chairman: Associate Professor.

Faculty: Engineering

The overall objective of this study was to develop and innovate sludge treatment technology especially related to sewage sludge combustion. And to investigate the thermal destruction of sewage sludge.

Sewage sludge characteristics were studied. Sewage sludge is composed of organic containing macro-nutrients such as nitrogen (N) and phosphor (P) and a number of trace of heavy metals as e.g. zinc (Zn). However, sewage sludge also contains components that are considered to be harmful to the environment. Moisture content was found to be70 %, specific gravity was equal to 1.107, and finally ash content was equal to 50 %.

The temperature effect at the different gas emissions during sewage sludge incineration using electrical muffle furnace was studied. It was found that increasing the temperature would increase both sulphur and nitrogen oxides (NO, NO2),whereas it would decrease carbon oxides (CO, CO2). The optimum

temperature for sewage sludge incineration with minimum air pollution was found to be 900 °C.

A study of the effect of limestone addition at the different gas emissions during sewage sludge incineration was performed. It was found that adding limestone during sewage sludge incineration will slightly increase nitrogen oxides by 5-10 % and carbon oxides by 0.02-11 % while it effectively decrease sulphur dioxide emissions by 65 % at 900°C. The optimum reduction in sulphur dioxide emissions can be achieved by using 2.0 Ca/S mole ratio.

The leaching characteristics of trace heavy metals were investigated to evaluate the stability of incinerated residues when finally disposed off. Effect of the acidity medium, in which incinerated ash to be disposed off, on the leachability of heavy metals content was also studied. It was found that incineration stabilises the sewage sludge heavy metals content and as pH value increases the leachability of heavy metals decreases. Cadmium was found to be the most stable heavy metal element by incineration followed by lead and zinc, on the other hand Mercury was the lowest stable heavy metal element.

At the end, A 20-liter pilot scale fluidised bed incinerator was designed for future studies.

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

PEMBAKARAN NAJIS ENAPCEMAR: KAJIAN MENGENAI PERESAPAN GAS DAN LOGAM BERAT

Oleh

MOHAMMED I. A. NASHBAT

Disember 1999

Pengerusi: Profesor Madya. Azni Haji Idris, Ph.D.

Fakulti: Kejuruteraan

Secara keseluruhan projek ini dijalankan untuk memajukan dan memperkenalkan sesuatu yang baru bagi teknologi perawatan enapcemar yang berkaitan dengan pembakaran najis enapcemar dan haba pemusnahannya.

Ciri-ciri najis enapcemar dikaji. Najis enapcemar adalah pengubah bagi makro- nutrien kandungan bahan organik seperti Nitrogen (N) dan Fosfor (F) serta mikro-nutrien seperti contoh: zink (Zn). Walaubagaimanapun, sisa kumbahan juga mengandungi komponen yang boleh mendatangkan bahaya kepada alam sekitar. Di mana kadar kandungan lembapannya telah dijumpai sebanyak 70%, nilai spesifik gravitinya bersamaan dengan 1.007 dan kandungan habuknya adalah bersamaan 50%.

Kesan suhu terhadap perbezaan pengeluaran pancaran gas telah dikaji semasa pembakaran najis enapcemar menggunakan dapur leburan elektrik. Didapati bahawa, penambahan suhu akan menambahkan kandungan Sulfur dan Nitrogen Dioksida seterusnya mengurangkan kandungan karbon dioksida. Suhu

optimum bagi pembakaran hangus najis enapcemar ialah 900°C dan dengan suhu ini ia dapat meminimumkan pencemaran ke atas udara.

Kajian ke atas penambahan batu kapur terhadap perbezaan peresapan gas semasa pembakaran hangus najis enapcemar telah dihasilkan. Di dapati bahawa dengan penambahan batu kapur semasa pembakaran najis enapcemar akan memberikan sedikit penambahan Nitrogen Dioksida sebanyak 5-10% dan Karbon Dioksida sebanyak 0.02-11%, sementara itu ia menurunkan pancaran Sulfur Dioksida sebanyak 65% pada suhu 900°C. Pengurangan optimum bagi pancaran Sulfur Dioksida dapat dicapai dengan menggunakan nisbah 2.0 Ca/S mode.

Ciri-ciri kakisan surih logam berat dikaji untuk menilai kestabilan pembakaran sisa bila ianya dibuang. Kesan keatas medium asid, di mana pemanasan abu dibuang, keboleh kakisan kandungan logam berat juga dikaji. Di dapati bahawa pembakaran dapat menstabilkan logam berat di dalam kandungan najis enapcemar di mana dengan kenaikkan nilai pH akan mengurangkan kakisan ke atas logam berat. Kadmium telah dijumpai sebagai elemen logam berat yang paling stabil melalui proses pembakaran diikuti dengan plumbum dan zink. Manakala Merkuri adalah elemen yang paling rendah kestabilannya.

Satu alat pembakar berbentuk seperti " lapisan pembendaliran " telah direka untuk 20 liter "Pilot Scale" bagi kajian di masa akan datang.

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I would like to express my deepest gratitude to my supervisor Dr. Azni Haji Idris for his guidance, encouragement and support through this project. I am indebted to Dr. Ahmad Tariq Jameel for his contribution to the design and construction of the equipment. I would also like to thank Dr. Fakhru'l-Razi Ahmadun for his guidance and co-operation.

Finally, I would like to express my indebtedness to my family and my friends for their support and belief in me.

Above all, I should say "THANK GOD", for without him, this study would not have materialised and be successful at all.

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LIST OF ABBREVIATIONS

BFBC	Bubbling Fluidised Bed Combustion
BFBI	Bubbling Fluidised Bed Incinerator
BOD	Biological Oxygen Demand
CETC	Canmet Energy Technology Centre
CFBC	Circulating Fluidised Bed Combustion
COD	Chemical Oxygen Demand
EPA	Environmental Protection Agency
EDX	Energy Dispersive X-rays
FBC	Fluidised Bed Combustion
FGD	Flue Gas Desulphurisation
HERS	Hyperion Energy Recovery System
ISV	In-Situ Vitrification
OFS	Oil From Sludge
PFBC	Pressurised Fluidised Bed Combustion
ppm	part per million
RM	Ringgit Malaysia
rpm	revolution per minute
UKM	University Kebangsaan Malaysia

CHAPTER I

INTRODUCTION

Background

Sewage sludge is unavoidable by-product of wastewater treatment. The increase in the requirement for the treatment of wastewater coupled with rapid industrial growth has created an over-proportional increase of sludge. In the same time, increasingly stringent environmental control regulations, which govern the disposal of sludge such as air quality, landfills, and ground water contamination, along with the decreasing availability of land for the encapsulation of wastes, create innovative technologies for sewage sludge final disposal.

Sludge may be defined as a solid-liquid waste mixture having a total solid concentration that may range from as low as 2,000 parts per million (ppm) to hundreds of thousands of ppm in some industrial sludges. Generally, sludge is defined as one, which can flow and can be pumped

The handling and disposal of sludges has long been considered the most troublesome phase of sewage and industrial waste treatment. With the evolution toward more efficient wastewater treatment plants, more difficult to handle sludges are produced. Thus, in the past phase of environmental control sewage sludge disposal has become an increasingly difficult problem.

Another facet of this problem is that with the volume of sludges from the domestic and industrial activity rising continuously, the land available for such sludge disposal and public tolerance of environmental pollution is decreasing. This situation has severely constrained the choice of acceptable disposal practices.

For this reason (primarily) there exist many alternatives for sludge treatment. Any number of systems is available for sludge stabilisation, for example, and the selection depends on site-specific criteria. Thus since each sludge and facility has unique characteristics, there is no universally acceptable "correct" way of managing sludge. The decision as to what system to use depends on many variables, often including political considerations and preconceived and perhaps biased notions of what does and does not work

The new approach for the treatment of sludge is what's known as "Recycling and utilisation of useful materials of sludge". Innovative technologies for sludge reuse stretches the boundaries of what is traditionally being considered beneficial reuse. If the process results into a useful end product with a reasonable

energy input, then the process worth using. A variety of innovative sludge processing technologies has not been yet proven in a full-scale installation.

One of the most popular methods of waste disposal is incineration. Incineration is the complete destruction of materials constituents. The material that is being destroyed is the waste product called sludge. Incineration thermally decomposes matter through oxidation, thereby reducing and minimising the wastes, and destroying their toxicity. It can be applied to industrial, municipal, and hazardous waste, provided that they contain organic substances that can undergo and sustain thermal degradation. There are three objectives incineration must accomplish: dry the sludge cakes, destroy the volatile content by burning, and produce a sterile or ash by heat to their inert.

Various types of incinerators are currently in use. The choice of an incinerator depends on the waste combustibility and its characterisation as liquid, ignition temperature, flash point, and flammability limits determine the necessary operating temperature, O2 concentration, and residence time for greatest waste minimisation. Among the other types of incinerators, fluidised bed incinerator is attracting increasing interest.

The formation of poisonous solid and gaseous by-products during sludge incineration is currently a source of public concern. These include the release of heavy metals and the emission of poisonous gaseous substances such as NOx, NO,

CO, CO_2, and SO_2. Therefore, for the future of sludge incineration, research and development must be directed towards reducing these emissions.

Many of the metals present in sludge can be useful as micronutrients. The presence of any of these metals in excessive quantities however is a major consideration in the system. At high concentration, it may be toxic to humans, animals and plants. Current use patterns for ash indicate its main application is as apozzolanic additive to Portland cement concrete where its natural cementitious properties can bring about cost savings. Other applications include uses as a road or railroad bed stabilizer, filler for asphalt mixes, lightweight aggregate, oil well grouting, mine subsidence, and fire control. However, it is suggested that these new uses must be examined much more carefully than they have been for their potentially adverse environmental effects.

Objective of the Study

In recent years there has been increasing concern about the amount and the quality of sewage sludge that must be disposed off. Finding an economically and environmentally acceptable method to dispose of sewage sludge is a pressing need. Overall objective of this study is to develop and innovate sludge treatment technology especially related to sewage sludge combustion. And to investigate the thermal destruction of sewage sludge More specifically,

1. To study the sewage sludge incineration characteristics using electrical furnace.
   a. To study the temperature effect on different gas emissions during sewage sludge incineration.
   b. To study the effect of limestone addition on different gas emissions during sewage sludge incineration.

2. To study the stability of the produced ash using leaching test.

Significance of the Study

Considering the facts, more stringent regulations and public concern has decreased the possibility of using sludge in agriculture, and the scarcity of suitable landfill areas. Incineration of sewage sludge is becoming an acceptable treatment alternative, due to high volume reduction, possible energy recovery, and some toxic destruction or reduction. This option is gaining more attention with the advent of proper air pollution control devices and highly effective cleaning systems. The formation of poisonous solid and gaseous by-products during sludge incineration is currently a source of public concern. Therefore, for the future of sludge incineration, research and development must be directed towards reducing these emissions. Fluidised bed combustion is a versatile technology capable of burning practically any waste fuel combination with low emissions. There remain some challenges for the technology to overcome, particularly in the areas of

improving sulphur capture and more information on the behaviour of trace metals are needed for achieving minimum flux of metals into the environment.

Thesis Organisation

The remainder of this thesis is organised as follows: Chapter 2 reviews sewage sludge related theories. First it contains a brief discussion about waste water treatment technologies, what are the process waste water go through before it produce sewage sludge. Second it reviews sewage sludge treatment technologies. Third sewage sludge incineration technology is discussed in details. Fourth fluidised bed incineration technology is also discussed in details. Finally sewage sludge incineration impact including air emissions and heavy metals is presented.

Chapter 3 describes the methodology used during our research, which includes physical and chemical sewage sludge analysis, ash analysis, air emission studies, and finally leaching test.

Chapter 4 includes the results optioned from the research with their discussions.

At the end chapter 5 presents the conclusions obtained and the future recommended studies.

CHAPTER II

LITERATURE REVIEW

Introduction

Sewage sludge is the accumulated, semiliquid material consisting of suspended, colloidal, and dissolved organic and inorganic matter, separated from wastewater during treatment. The amount of sludge generated from sewage treatment plants is increasing in proportion to the expansion of sewerage infrastructure. At present 3 million cubic meters of sewage sludge is produced annually in Malaysia and the total cost of managing this sludge is estimated at RM 1 billion (Abdul Kadir, 1998). This figure is expected to rise to 7 million cubic meters by the year 2020. Therefore, it is becoming more important to consider treating and utilizing sewage sludge for useful applications.

The object of sewage treatment is to reduce the content of polluting matter to a level at which the resulting effluent can meet local requirements for discharge to natural water bodies.