UNIVERSITI PUTRA MALAYSIA

# A FULL-SCALE COMBINED ANAEROBIC-AEROBIC SYSTEM FOR TREATMENT OF MELAMINE FORMALDEHYDE WASTEWATER

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By

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TO ALL MY TEACHERS....

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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The objective of this full scale study is to determine the effectiveness of the combined two stage anaerobic-aerobic processes to treat high strength melamine formaldehyde (MF) wastewater at ambient temperature. The raw wastewater with COD concentration of between 25,000 to 50,000 ppm at normal operating condition. Two-stage physical/chemical treatment processes were carried out in this experiment to ensure consistent wastewater stream to be treated at the downstream anaerobic BioFil and aerobic system. The two BioFil reactors total combined volume of 70.0 $m^3$ (35 MT each) and the Aeration Tank has a capacity of 5.0 $m^3$ to cater for a flow rate of 15-25 $m^3$/day. Concentration of biomass was achieved through entrapment in the macrostructure of cosmo (HDPE) balls used in the BioFil reactors. Hydraulic retention time (HRT) for BioFil was controlled by centrifugal pump at 24, 18, 12 and 6 hours with corresponding organic loading of 2.4, 4.8, 9.7 and 38.8 kg COD/$m^3$/day. Under steady state condition, the highest percentage removal achieved was COD 86.3%, BOD 87.0%,

TSS 84.4% and 86.8% for VSS at HRT 24 hours. Generally the BioFil was able to stabilized at a period of 5 to 8 days when a new loading rate was applied. Accordingly, the HRT for Aeration Tank (AT) was 8, 6 and 4 hours with substrate loading of 13.9, 55.4 and 145.2 kg COD/$m^3$/day. Under steady state condition in AT, the highest percentage removal of organic matter was observed at HRT 8 hours, with COD 86.2%, BOD 86.5%, 80.2% and 86.0% for TSS and VSS respectively. The cosmo balls used in the BioFil proven to be an effective carrier material which functioned as a separation device thus limiting biomass being washed out. The combined anaerobic-aerobic system is a suitable process to treat high strength wastewater. Based on this full scale study, higher efficiency of this system can be anticipated if longer HRT is allowed in the Aeration Tank.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian daripada syarat untuk Ijazah Master Sains.

**KAJIAN BERSKALA PENUH KEATAS SYSTEM KOMBINASI ANAEROBIK-AEROBIK DALAM MERAWAT SISA AIR BUANGAN MELAMINE FORMALDEHYDE**

Oleh

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Tujuan kajian berskala penuh adalah untuk menentukan keberkesanan gabungan dua peringkat proses anaerobik BioFil-aerobik untuk merawat sisa air buangan melamine formaldehyde (MF) pada suhu persekitaran. Sisa air buangan ini mengandungi kepekatan COD diantara 25,000 to 50,000 ppm pada keadaan operasi yang normal. Dua tahap rawatan fizikal/kimia telah dijalankan untuk memastikan ciri-ciri air sisa yang konsisten dirawat oleh sistem BioFil dan aerobik yang seterusnys. Kedua-dua reaktor BioFil mempunyai jumlah gabungan isipadu sebanyak 70 $m^3$ dan tangki aerobik mempunyai muatan sebanyak 5.0 $m^3$ bagi merawat kadar aliran air sisa sebanyak 15-25 $m^3$/hari. Kepekatan biomas dapat dicapai melalui proses pengumpulan dalam struktur makro bebola cosmo yang digunakan dalam BioFil ini. Masa tahanan hidrolik bagi BioFil dikawal oleh pam emparan pada 24, 18, 12 dan 6 jam dengan perubahan beban organik sebanyak 2.4, 4.8, 9.7 dan 38.8 kg COD/$m^3$/day. Dalam keadaan mantap, peratus penyingkiran tertinggi yang dicapai adalah COD 86.3%, BOD 87.0%, TSS 84.4% dan

86.8% bagi VSS pada HRT 24 jam. Pada amnya, BioFil dapat distabilkan pada tempoh 5-8 hari dibawah perubahan tahap beban yang baru. HRT pada tangki aerobik (AT) adalah 8, 6 dan 4 jam dengan bebanan sebanyak 13.9, 55.4 dan 145.2 kg COD/$m^3$/day. Dalam keadaan mantap di AT, peratus penyingkiran bahan organik dapat diperhatikan pada HRT 8 jam dengan COD 86.2%, BOD 86.5%, 80.2% dan 86.0% untuk TSS serta VSS. Bebola cosmo yang diguna di BioFil terbukti berkesan sebagai bahan pengangkut dalam pemisahan dan seterusnya menghadkan biomas daripada dibasuh keluar. Kombinasi sistem anaerobik-aerobik adalah proses yang sesuai untuk merawat air sisa buangan yang mempunyai kepekatan tinggi. Berdasarkan kajian ini, keberkesanan yang lebih tinggi boleh dicapai sekiranya HRT yang lebih lama diperuntukan bagi tangki aerobik.

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## TABLE OF CONTENTS

# LIST OF TABLES

## LIST OF FIGURES

## LIST OF PLATES

## LIST OF ABBREVIATIONS

| | |
|---|---|
| AF | Anaerobic Filter |
| AT | Aeration Tank |
| BOD | Biochemical Oxygen Demand |
| COD | Chemical Oxygen Demand |
| EC | European Community |
| FRP | Fibreglass Reinforced Polypropylene |
| HDPE | High Density Polyethylene |
| HRT | Hydraulic Retention Time |
| MF | Melamine Formaldehyde |
| OLR | Organic Loading Rate |
| SSC | Steady State Conditions |
| SRT | Solids Retention Time |
| TSS | Total Suspended Solids |
| UASB | Upflow Anaerobic Sludge Blanket |
| VSS | Volatile Suspended Solids |
| WWTP | Wastewater Treatment Plant |

# CHAPTER I

# INTRODUCTION

Malaysia, being bestowed with rich resources, both renewable and non-renewable, has been experiencing high rates of economic growth and development. Due to the pace of industrialization that has accelerated in recent years (the manufacturing sector accounting for more than 70% of Malaysia export) a significant proportion of mainly organic wastewater generated has been identified as one of the major sources of water pollution and malodours which are the subjects of frequent public complaints. Pollution problem therefore poses as an industrial crime and inevitably draws in water pollution and other waste related problems. Much of this industrial wastewater, in its raw form, is of medium to high strength and is therefore ideal feedstock for first-stage anaerobic treatment.

The demand for very effective and cost saving treatment systems to treat sewage and industrial effluent is becoming rather immense. New industries produce complex effluents while the traditional factories such as palm oil mills, rubber and other chemical industries continue to generate large volume of high strength organic pollutants which require a lot of treatment and yet is often not economical.

In general, where readily biodegradable high-strength wastewater with fairly consistent waste characteristics is concerned, anaerobic digestion is almost invariably the most appropriate technology to be employed for the first-stage treatment. This system is notably capable of handling recalcitrant waste in a cost-effective way.

Anaerobic treatment in the form of anaerobic ponds is said to be extensively used in the Malaysian agroindustrial sector, primarily in the palm oil and rubber processing industries. On the other hand, its adoption by the local waste generators is still relatively limited. Nevertheless, there has been a growing interest among Malaysian researchers in anaerobic biotechnology with a view to harnessing the technology for waste treatment based on the concept of resource recovery and utilisation while still achieving the objective of pollution control.

The many successes and rapid developments achieved in anaerobic digestion technology in the past two decades have essentially been prompted by the introduction of increasingly stringent environmental legislations in many countries, coupled with the exponential rise in energy costs in the 1970's. The energy crisis helped reveal an additional role for anaerobic digestion which was to produce methane gas as an alternative fuel, stimulating worldwide research and development of anaerobic digestion.

Large scale applications of anaerobic digestion in the form of properly designed reactors with energy recovery has been developed particularly in the palm oil, rubber and alcohol fermentation industries in Malaysia. The methane rich biogas produced as a by

product of the anaerobic process is, in most cases, exploited as a useful biofuel for power or heat generation thereby offsetting the cost of treatment, or even resulting in profitability.

The conversion of agricultural wastes, animal manure in particular, into a renewable energy resource has been the focus of intensive research for well over two decades. Extending the anaerobic digestion process to recover methane has considerable potential beyond the farm to other industries with a waste stream characterization similar to livestock manure. Example industries include processors of milk, meat, food, fiber and pharmaceuticals. Some of these industries already recover methane for energy. Promising future waste-to-profit activities may enhance the economic performance of the overall farm manure management system.

Anaerobic digestion has become a mature technology in the hands of a small number of constructors, distributed throughout the EC. A number of problems have been encountered during the operation of anaerobic digesters. These problems have been documented at length in the literature. All of them now have solutions and remedies.

In tropical countries, however, where local temperatures are more favourable to the biomethanation process, anaerobic treatment of domestic wastewater has proven economically and technically attractive. Due to continuing problems in mastering active biomass granulation and its sludge volume index, most granulation and its sludge volume index, most UASB reactors presently include a decanter.

Biogas produced by the anaerobic digestion process is quite similar to "natural" gas as it is extracted from the wellhead, and is suitable for use in engine/generator to produce electricity. When biogas is used to produce electricity, there is the added potential for harvesting thermal energy from the engine's exhaust and cooling system (Walsh, et al., 1988).

The annual utilization of biogas in the EC is approximately in order of magnitude larger than in the USA. In contrast, the annual utilization of landfill gas in the USA in 1990 was around 4.3 x $10^9$ $m^3$. This was about five times the volume of landfill gas recovered in the EC (around 750 x $10^6$ $m^3$). Anaerobic digestion has become a mature technology in the hands of a small number of reputable companies distributed throughout the EC. Table 1 lists the major companies involved in the construction of these digestors and some of them had exported their know-how to a significant extent.

The biogas plants could be divided into two general groups on the basis of the primary activity of the user. There were either agricultural plants, located on farms and using farm wastes (mainly animal manure), or industrial plants usually located in agro-food companies, mainly treating wastewater.

Table 1: Number of Full Scale Biogas Plants Built Inside and Outside the European Community by the Major and Still Active Companies Located in the EC

| Company Names | Country | Industrial Waste | Agricultural Waste | Number of Plants in The EC | Number of Plants Outside The EC |
|---|---|---|---|---|---|
| Biotim | Belgium | X | | 28 (90) | 27 (90) |
| Bigadan' | Denmark | X | X | 15 (90) | 1 (90) |
| Degremont | France | X | | 16 (87) | - |
| SGN | France | X | | 12 (87) | - |
| Emmepi | Italy | | X | 13 (87) | - |
| RPA | Italy | X | X | 21 (87) | - |
| Snamprogaetti | Italy | X | X | 27 (87) | - |
| Gist-Brocades | NL | X | | 40 (90) | 37 (90) |
| Paques | NL | X | | 34 (90) | 47 (90) |
| Sonergil | Portugal | | X | 21 (90) | - |
| Farm Gas | UK | X | X | 50 (90) | - |

'Now Kruger-Bigadan. Values in parentheses refer to the year of validity of the data presented. The plants constructed by Esmil were included under Gist-Brocades, according to the list furnished by the manufacturer.

Pauss and Nyns (1990)

Conventional designs of biogas digesters are either cylindrical, spherical or boxlike structures. For animal manure, water-proof concrete is commonly used. Mild steel sheets are used for cylindrical or column digesters. For a large volume digester, the use of metal sheets is quite expensive. In biogas systems where the product is not of high value, a lower cost of capital investment is desired.

The idea of a new design and configuration of a biogas reactor was conceived based on the following considerations:

(i) The biogas reactor must be able to handle high organic loading.

(ii) It must contain an efficient microbial support material.

(iii) It can operate continuously.

(iv) It is easy to scale-up.

(v) It should be operated in a stage wise manner.

Realizing the importance of the environmental issues that relate to industries, research work carried out at the Department of Chemical and Environmental Engineering, UPM are centered on producing bioreactors which possess very high microbial degradation capability to overcome the highly polluting industrial waste effluent. There are three type of bioreactors under study, namely biofilter, fluidized bed (FB) and upflow anaerobic sludge blanket (UASB).

Scale-up studies were intensified over the last three (3) years to produce the first novel bioreactor for the palm oil industry. The final outcome of research was the development of an anaerobic system called "BioFil" which is presently fully commercialized as full scale plant. A patent was applied on the process in July, 1995 of the anaerobic version. The BioFil establishes growth of the anaerobic organisms on a hollow balls packing which is made of HDPE material and is known as cosmo balls. The packed filter media, while retaining biological solids, also provides a mechanism for separating the solids and the gas produced in the digestion process.