

**OPTIMIZATION OF SLUDGE DISINTEGRATION FROM IWK-  
BUNUS SEWAGE TREATMENT PLANT FOR ENHANCED  
BIOGAS YIELD**

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I declare that this dissertation entitled “*Optimization of Sludge disintegration from IWK-Bunus Sewage Treatment Plant for Enhanced Biogas Yield*” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date: 20<sup>th</sup> January, 2012

To my beloved Parent, and to the comfort of my eyes: my Wife and Children

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## ABSTRACT

Biogas is a source of renewable energy (fuel) produced through anaerobic digestion of biomass. Sewage sludge is a form of biomass that is found as sediment (slurry) product of waste water treatment plants. This research is aimed at optimizing the yield of the biogas produced from Indah Water Konsortium- Bunos sewage treatment plant (STP) through sewage sludge disintegration processes. By optimizing the yield, the STP can generate its own future heat and power demands that can possibly be exported to the grid. To achieve that, the plant was physically studied on its operations. The current population equivalent (PE) of the plant is 175,000 instead of the installed capacity of 375,000. This constitutes towards low total solids (TS) and volatile solids (VS) of about 1.89 and 1.38% respectively, and a low overall biogas yield of 1500 m<sup>3</sup>/day (56% VS reduction) instead of recommended 2200 m<sup>3</sup>/day (80% VS reduction). Thermal, chemical and thermochemical disintegration techniques were employed to investigate their impact on improving the biogas yield during anaerobic digestion. Modeling and Optimization of the disintegration processes were carried out using STATISTICA. The results of ANOVA and multiple regression analysis show that the optimum variables for the thermal disintegration are: 88°C, 227 rpm and 21 min, with actual degree of disintegration (DD) of 55.4%. For chemical disintegration, the optimum variables are 2.85M NaOH, 229 rpm and 21min and a corresponding optimum DD of 52.68%. The optimum DD for thermochemical disintegration is 61.45% at: 88°C, 2.29M NaOH, and 21 min. Biogas yield was improved by 60%, 15% and 36% v/v using the thermal, chemical and thermochemical disintegration techniques respectively. This shows that yield of biogas can be enhanced through disintegration process, and eventual higher cogeneration potential can be exploited.

## ABSTRAK

Biogas ialah sumber boleh diperbaharui (bahan api) yang dihasilkan melalui pencernaan aerobik biojisim. Enap cemar kumbahan ialah satu bentuk biojisim yang boleh ditemui sebagai produk mendapan loji rawatan air sisa. Kajian ini bermatlamat untuk mengoptimumkan penghasilan biogas daripada Indah Water Konsortium-Bunus STP melalui proses penyepaian enap cemar kumbahan. Dengan mengoptimumkan penghasilan, STP boleh menjana permintaan haba dan kuasa sendiri dan berkebarangkalian untuk diekspot grid. Bagi mencapai matlamat, operasi loji telah dikaji secara fizikal. Nilai semasa PE bagi loji ialah 175, 000 berbanding dengan kapasiti 375, 000 semasa pemasangan. Ini terdiri daripada TS dan VS yang rendah sebanyak 1.89% dan 1.38 % masing-masing dan menghasilkan biogas yang sedikit sebanyak 1500 m<sup>3</sup>/day (56% VS pengurangan) peratus yang disyorkan iaitu 2200 m<sup>3</sup>/day (80% VS pengurangan). Teknik penyepaian haba, kimia dan termokimia telah digunakan untuk menyiasat kesan pencernaan aerobik dalam meningkatkan hasil biogas. Pemodelan dan pengoptimalan untuk proses penyepaian telah dijalankan dengan menggunakan STATISTICA dan keputusan ANOVA dan pelbagai analisis regresi menunjukkan bahawa pemboleh ubah optimum untuk penyepaian haba ialah: 88°C, 227 rpm dan 21min dengan DD sebanyak 55.4%; manakala untuk penyepaian kimia ialah 2.85M NaOH , 229 rpm dan 21 min. DD optimum untuk penyepaian termokimia ialah 61.45% pada: 88°C, 2.29M NaOH, dan 21 min. Hasil biogas telah meningkat sebanyak 60%, 15% dan 36% v/v setelah mengaplikasikan teknik penyepaian haba, kimia dan termokimia. Ini menuhjukkan bahawa hasil biogas boleh ditingkatkan melalui proses penyepaian dan secara tak langsung potensi kogenerasi yang lebih tinggi dapat dicapai.

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## LIST OF ABBREVIATIONS

AD	-	Anaerobic Digestion
ANOVA	-	Analysis of Variance
BBD	-	Box-Behnken Design
CD	-	Chemical Disintegration
COD	-	Chemical Oxygen Demand
DD	-	Degree of Disintegration
df	-	Degree of Freedom
HRT	-	Hydraulic Retention Time
IWK	-	Indah Water Konsortium
MS	-	Mean Square
PE	-	Population Equivalent
RSM	-	Response Surface Methodology
SCOD	-	Soluble Chemical Oxygen Demand
SS	-	Sum of Squares
STP	-	Sewage Treatment Plant
TC	-	Thermal Disintegration

TCD	-	Thermochemical Disintegration
TCOD	-	Total Chemical Oxygen Demand
TOC	-	Total Organic Carbon
TN	-	Total Nitrogen
TS	-	Total Solids
VS	-	Volatile Solids
VFA	-	Volatile Fatty Acids
WAS	-	Waste Activated Sludge

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Background**

There has been a worldwide drive for minimizing material and energy resources via sustainable living to save the earth for future generations. The concerted efforts made by many countries such as the “Kyoto Protocol” initiatives where most of the industrialized nations agreed to reduce their emissions of greenhouse gases (GHGs) is among the steps in the right direction.

The pressure on the limited resources of fossil fuels to meet the demand is another point of concern, not to mention the inherent environmental impacts associated with the use of conventional fossil fuels for energy.

These broad issues challenging the present and future generations necessitate the evolution of “cleaner” technologies and also searching for alternative fuels; that are renewable and have no or little environmental problems associated with its use. This gives rise to considerable changes being carried out in the energy and chemical industry

in searching for cheaper, more abundant and cleaner resources; as a response to the aforementioned challenges.

It has been stated (Deublein and Steinhauser, 2008) that in the future, countries may employ different technologies for its energy requirement, based on their respective climatic and geographic location. This means that in the future, more and more novel and cleaner technologies may emerge in response to the limited fossil fuel resources; thereby switching to most available and renewable energy resources found or most available in a certain country.

Among the known renewable energy resources are the famous solar, hydro, geothermal, wind, wave and biomass. This combination accounts for about 14% of primary energy demand of the world, from which biomass alone constitutes about 10% (Converti, 2009).

Biomass refers to the biological matter from both plant and animal living or recently dead. Biomass is rich in carbon, but not yet a fossil material. Agricultural wastes, excrement and bio-wastes from households and the industries are all biomass. Biomass stands the chance to be the worldwide energy resource substituting the fossil resources. This is because biomass derived energy can be converted to various forms of usable energy such as heat, steam, hydrogen, biogas, electricity, biodiesel, bioethanol and so on.

Converti (2009) asserted that in the next few decades, bioenergy will be the most significant renewable energy source until when solar and wind are fully harnessed. Biomass can be converted into solid, liquid or gaseous fuels by different processes which include:

(i) Thermo-chemical Conversion- among which are combustion, gasification, pyrolysis etc.,

(ii) Biochemical Conversion- including fermentation, aerobic and anaerobic digestion and

(iii) Physico-chemical transformations- involving; compression, extraction, transesterification (Deublein and Steinhauser, 2008).

The most widely used method of converting biomass to energy is the anaerobic digestion because of its cost effectiveness, especially in the process of biogas manufacture. Biogas may be generated from many sources of biomass such as grasses, leaves, weeds, woods, animal manure, algae, compost, sewage sludge etc. (Converti, 2009).

Anaerobic digestion is the decomposition of organic material in the absence of oxygen into its simpler forms by the help of microorganisms (Monnet, 2003). The decomposition is a series of complex reactions that convert biopolymers such as carbohydrates, proteins and lipids to simpler forms producing a mixture of gases chiefly methane of about 60-70% composition (Lu, 2006).

As stated earlier, among the biomass used for biogas production is the sewage sludge. Sewage sludge is a “by product” of wastewater treatment process which is generated by sedimentation. The sewage sludge is rich in microorganisms, organic matter and harmful pathogens. Sewage sludge has been another environmental problem in landfills, aesthetically displeasing to the sight of individuals, and at the same time it is a great potential source of biogas owing to its compositions.

About 210 million tons of sewage sludge is being produced in the United States; and more than 50 million cubic meter is generated annually in Japan (Alam *et al.*, 2007). In Malaysia, sludge from sewage treatment plants is the largest contributor of organic pollution to water resources accounting for about 64.4% (Alam, *et al.*, 2007). Approximately 4.2 million cubic meter of sewage sludge is produced by the Indah Water Konsortium (IWK) annually, costing about RM 1 billion for its management

(Alam, *et al.*, 2007). The volume is expected to rise up to 7 million cubic meters by the year 2020 (Alam, *et al.*, 2007), due to the fast growth of Malaysia as a country.

IWK in its own right, is a potential great producer of biogas, thereby, making it potentially energy self-sufficient as well as standing the chance to contribute its own quota in saving the earth and at the same time enjoying financial savings.

However, generating biogas from sewage sludge is a hectic task, demanding a lot of attention to operating variables. Biogas generation depends on several operating parameters; such as total solid content, temperature, pH, retention time, carbon to nitrogen ratio (C:N), mixing etc., which need proper monitoring and control to achieve maximum yield of biogas.

Pretreatment of the sludge itself may help achieve a better yield of biogas. Screening and sorting out of non-biodegradable matter, sludge thickening and disintegration are among the major methods of pretreatment for the sludge for higher yield of gas production. Upgrading the produced biogas also improves the methane content of the biogas. Processes like desulfurization, hydrogen and carbon dioxide removal among others are employed. In some cases, the plant process parameters (e.g. Temperature, pH, total solids etc.) need to be improved in order to enhance the biogas yield.

This research work is based on the IWK, Bunus STP sludge which undergoes anaerobic digestion for its stabilization and biogas is generated thereof. The objective of the research is to investigate the plant operation and the sludge quality, with the aim of optimizing the biogas yield and its quality which can subsequently be utilized for in-house power as well as possibility of selling it to the national grid.

## **1.2 Problem Statement**

Indah Water Konsortium (IWK) STP is a potential producer of biogas that can be optimized and upgraded for self-consumption of energy and / or selling it out to the grid. Currently, Bunus STP produces 1,500 m<sup>3</sup>/day of biogas (56% VS reduction) instead of recommended 2200m<sup>3</sup>/day (80% VS reduction). Therefore there is need to conduct a detailed research study on the plant. The total waste activated sludge (WAS) volume generated throughout Malaysia from the IWK- STPs annually is over 4.2 million cubic meter .This high volume of WAS is alarming and over RM 1 billion is spent for its management. Hence the need to reduce generation of the sludge and by doing so, the biogas generation is enhanced. In order to achieve this, the WAS needs to be disintegrated (pretreated). Therefore the IWK STPs potentials for cogeneration of heat and power can be exploited to earn both environmental and economic benefits.

## **1.3 Objectives**

The objectives of the research work include:

- (i) To investigate Bunus STP operation in order to identify key issues to be improved in order to optimize the biogas yield.
  
- (ii) To establish the optimum operating variables for disintegration processes to maximize biogas yield.

## **1.4 Scope of Research**

Scope of the work to achieve the set objectives is:

- (i) To study the plant anaerobic digestion system in order to identify factors responsible for the low yield of biogas.
- (ii) To characterize the sludge so as to determine its quality and determine the need for improvement.
- (iii) To conduct thermal and chemical sludge disintegration as well as the combination of the two methods to increase sludge solubilization for better yield.
- (iv) To establish optimum conditions for sludge solubilization from the effects of temperature and alkaline concentration as well as time and speed of mixing on the various methods of disintegration.
- (v) To conduct biogas generation experiment using raw and various disintegrated sludge samples to find out the effect of disintegration on biogas yield.

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