# PYROLYSIS BEHAVIOR OF SEWAGE SLUDGE PRODUCED AT JASIN CENTRAL SEWAGE TREATMENT PLANT

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***Abstract*****—** Thermochemical conversion of solid fuel is not a new technology today. Pyrolysis is one of the most famous technique that have been widely used in thermochemical conversion process. Pyrolysis of sewage sludge is an economical method where it can manage the volume and the impacts regarding its disposal, thus enabling it into valuable energy and fuel. Sewage sludge can also be defined as semi biomass, but somehow it might complicated than other biomass when it comes to thermochemical conversion. The thermogravimetric analyzer (TGA) is being used to characterize the pyrolysis behaviour of the sewage sludge from Jasin. The proximate and ultimate analysis of the sewage sludge are being compared from the previous researched. Although the pyrolysis of sewage sludge had been studied years ago, but it requires a lot of understanding of its thermal properties.

*Keywords*— ***Sewage sludge, thermochemical conversion, pyrolysis, TGA***

## 1. INTRODUCTION

### 1.1 Research Background

With the increase of world population nowadays, the more the consumption of energy are needed to sustain the development of the world. The fast rate of urbanisation and the rapid grow of the world population also have increase the volume of wastewater produced from the ongoing daily routine. This have led to the stringent requirement of the sewage sludge treatment as well as the increase of the sewage sludge volume from the process treatment. The production of sewage sludge is estimated produced at the rate of 0.1 – 30.8 kg per population over a year (Syed-Hassan et al. 2017) and China is the highest producer of sewage sludge around 20 million tons annually (Fan, Zhou, and Wang 2014). The sewage sludge volume was forecast that it will continue increases through the years based on the growth development population and urbanisation.

There are some methods were used in order to handle the disposal of the sewage sludge such as for agriculture as a fertilizer for the plants and landfill disposal. However, despite these methods have been applied, the amount of sewage sludge remained still high. According to Thipkhunthod (2006), the problem will not solved as it will cause subsequent problems and also need a secondary treatment. For instance, the untreated sewage water in certain areas can be contaminated and cause a serious disease such as diarrhoea and make the environment unhealthy.

Pyrolysis of sewage sludge is a promising way to handle sewage sludge disposal as an alternative way for the thermal processing pollution and high consumption of energy. Pyrolysis is one of the thermochemical process that converting biomass into various types of energy and chemical products including liquid bio-oil, solid biochar and pyrolytic gas (Kan, Strezov, and Evans 2016). Pyrolysis is the thermal decomposition of biomass at certain temperature in the absence of oxygen. Basically, this pyrolysis can be classified into three groups: i) conventional pyrolysis, ii) slow pyrolysis, and iii) fast and flash pyrolysis. Conventional pyrolysis operate at very low temperature and long residence times which consist slow, irreversible, thermal decomposition of the organic components. By operating at moderate temperature and moderate residence times, slow pyrolysis is widely used for the production of coal. Fast pyrolysis or flash pyrolysis usually run at high temperature but with low residence times. Compare to the slow pyrolysis, fast or flash pyrolysis contribute mostly to the production of bio oil around 75% where 12% char and 13% gas (Conversion n.d.).

The pyrolysis of sewage sludge can be classified as one of the most complicated and quite challenging in thermochemical conversion as it has unique properties compare to other solid fuels such as lignocellulosic biomass and coal (Syed-Hassan et al. 2017). Different biomass will have different pyrolysis behaviour such as heating rate, temperature, residence time and also the composition of itself. In order to know the pyrolysis behaviour of sewage sludge, it requires a better understanding of its thermal properties and reaction kinetics (Thipkhunthod et al. 2006). Thermogravimetric analysis (TGA) is the best method to illustrate the kinetic and thermal properties of the sewage sludge. By taking sample of sewage sludge produced at Jasin, the pyrolysis behaviour of the sludge was investigated by means of thermogravimetric analysis.

### 1.2 Problem statement

Pyrolysis of sewage sludge is an alternative way to manage the sewage sludge from being disposed without any treatments. The conversion of sewage sludge into energy and fuel by pyrolysis is the best method for utilizing the sewage sludge, thus it can reduce the amount of sewage sludge produce. Although pyrolysis is one of the most thermochemical process that had been widely used for the conversion of any biomass to energy and fuel, but for pyrolysis of sewage sludge, it needs a lot of understanding and further study as its deviation of properties compare to biomass. For instance, pyrolysis of sewage sludge is much complicated than pyrolysis of biomass. Despite it deviation from others biomass, sewage sludge can become one of the most important solid fuels to replace biomass. There are three main products produced when pyrolysis is applied to the sewage sludge which were liquid, gas and char. But not all the sewage sludge will have the same compositions even it is in the same treatment plant.

### 1.3 Objectives

The main purpose of this study is to investigate the behavior of the sewage sludge produced at Jasin Central Sewage Treatment Plant and its differences from other sewage sludge. The objectives of this study are:

a) To study the pyrolysis behavior of the sewage sludge from Jasin Central Sewage Treatment Plant

b) To investigate the effect of pyrolysis temperature and the sewage sludge compositions

# 1. METHODOLOGY

## 2.1 Introduction

In this chapter, the methodology that is used is lab activities such as collecting samples and analysing data. Figure 3 below shows an overview process for this chapter.

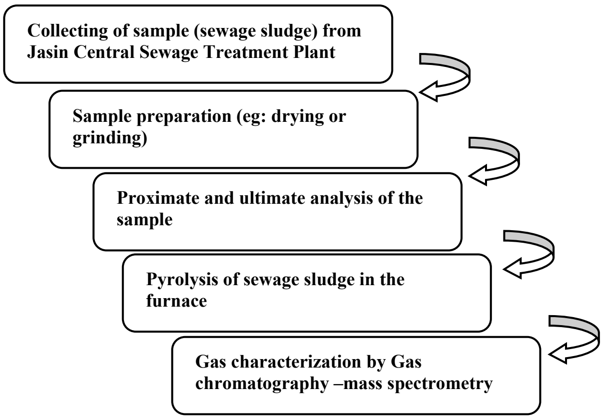


***Figure 2: An overview process***

## 2.2 Preparation of sample

In this case, the sample is collected from Jasin Central Sewage Treatment Plant that enough to run the experiment. The collected sewage sludge may consist of varieties of components as it was collected from the housing area, industrial and many other places. But the major contributions to the production of sewage sludge is from the residential area. The wet samples then is being dried for 24 hours at 105 °C by using an oven and after that the samples was milled and sieved around 50-200 µ m in diameter (Li n.d.).

## 2.3 Sample characterization

### *I. Proximate and ultimate analysis*

The sewage sludge characteristics were analyzed by following to ASTM D3172-89. This method will give proximate analysis of the sewage where to measure the composition of the fixed carbon (fc), ash content, moisture and volatile matter of the sewage sludge while for ultimate analysis, ASTM D3176-89, this provides weight percentage of hydrogen, carbon, nitrogen, sulphur and oxygen (Thipkhunthod et al. 2005).

### *II. Thermogravimetric analysis (TGA)*

The samples will be pyrolyzed using a thermogravimetric analyzer as shown in Figure 3.4 below. Approximately around 10 mg to 50 mg was taken from the sample for each experiment under non-isothermal conditions where the temperature starts from 300-900°C. The nitrogen flowrate and heating rate is being centralized at the range of 20-100 ml min-1 and 10-20°C min-1 respectively (Thipkhunthod et al. 2006). From TGA, the proximate analysis of the sewage sludge can be identified along with the TGA/DTG curve for measure the mass loss of the sewage sludge.

### *III. Gas evolution*

In order to determine the characteristics of the pyrolytic gas, the evolution of various gases will be analyzed in the gas chromatography-mass spectrometry (GCMS) under helium atmosphere. Before that the sewage sludge will undergoes pyrolysis inside a furnace for about 300-900°C and at a certain residence time. The pyrolytic vapour then will be connected to the GC to characterize the gas that produce from the pyrolysis of sewage sludge.

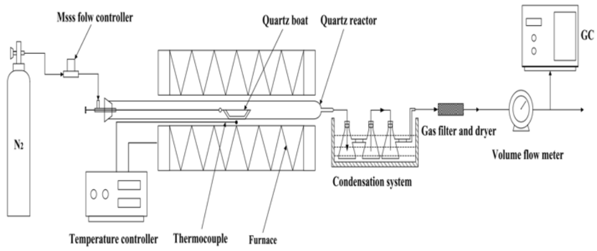


*Figure 2.5. The pyrolysis process of sewage sludge* (Li n.d.)

Figure 2.5 above illustrates how the process of sewage sludge from pyrolysis of the sewage sludge to the analysis of gas produce via GCMS. The produced pyrolysis gas then will pass through the condensation unit as condensate where in this experiment the objective is to get the pyrolytic gas. The volume of the non-condensable gas is measured by using a gas flow meter unit and the gas being collected periodically through the gas bags and then will be analyzed.

# 3. RESULTS AND DISCUSSION

## *3.1 Sewage sludge characteristics*

Table 3 below shows the characteristics of the sample from the previous experiment. The volatile matter and ash contents are dominating the compositions of Jasin sewage sludge with 24.08 % and 60.05 % respectively. According to P.Thipkhunthod (2005) through his research, he compared the compositions of the sewage sludges from different sources and as expected the compositions of sewage sludge are mainly volatile matter and ash contents. The heating value of the sample was contributed by these two compositions whereby the volatile matter is the major contributor for the heating value of the sewage sludge. The moisture content for Jasin sewage sludge is much lower since it undergoes drying process.

In terms of elemental compositions, the value of hydrogen and nitrogen can be affected based on the sources of the sewage sludge. In our case, Jasin central sewage treatment plant are mainly collected from household and community residence. The possibilities to have higher in nitrogen is high as the main source of nitrogen comes from peptides and proteins and also from fatty acid and sugar (Syed-Hassan et al. 2017) where all of these sources are the basic needs in our daily life.

***Table 3 Characteristics of Jasin sewage sludge***

| Property | Value |
|---|---|
| Proximate analysis (wt %)* | |
| Moisture | 4.31 |
| Volatile matter | 24.08 |
| Ash | 60.05 |
| Fixed carbon | 11.56 |
| Ultimate analysis (wt % )* | |
| Carbon | 28.7 |
| Hydrogen | 4.63 |
| Nitrogen | 2.72 |
| Sulphur | 1.54 |
| Oxygen | 19.8 |
| Calorific value (HHV) | 3031 kcal/kg |

**based on dry basis*

***Table 3.1 GC–MS analysis results for sewage sludge vapour***.

| Retention time (min) | Compound name |
|---|---|
| 1.9720 | Isopropylamine |
| 2.0440 | 4-Penten-2-ol, 3-methyl |
| 2.3024 | 1, 3-Cyclopentadiene |
| 3.0875 | Benzene |
| 4.8309 | Cyclobutene, 2-propenylidene |

Results from GC-MS analysis above shows that most of the component that presence in the sewage sludge itself are mainly from aromatic component. The component exist in the sewage sludge may be depends on what types of waste that be collected through the Jasin Central Sewage Treatment Plant such as household area or industrial area. Normally aromatics hydrocarbons comes from small factories and public utilities. For instance, this aromatic hydrocarbons are very harmful even at low concentration especially benzene as it can causes toxicity to soil and water ecosystem (Mrowiec and Suschka 2010). Furthermore, the formation of these compound can be related to the pyrolysis temperature. At temperature around 600 ° C, the unstable components of primary volatiles undergo further thermal decomposition resulting in the formation of low carbon molecular weight gases and more stable aromatic compounds (Andrés et al. 2016).

### *3.2 Thermochemical conversion of sewage sludge*

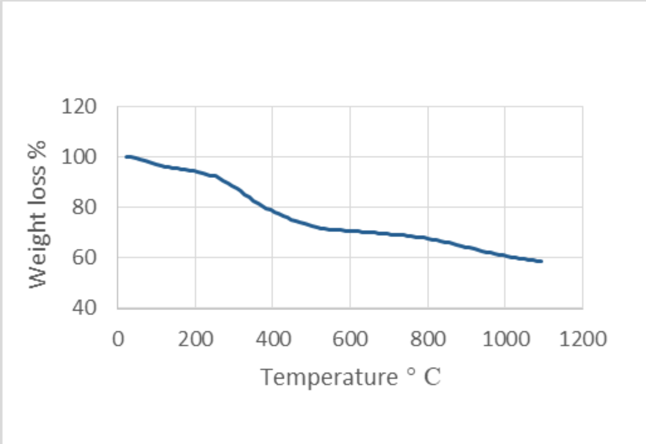


***Figure 3. TGA curves of weight loss of sewage sludge***

Figure 3 above shows how the weight of sewage sludge loss throughout the temperature. As general the weight loss of the sewage sludge fluctuate as temperature increases. At a starting of pyrolysis process, around 50° C to 150 ° C, the weight loss of the sewage sludge does not decrease too much only for 0.86mg. But significantly major loss when the temperature started to reach from 170 ° C to 550 ° C. At this temperature, the sewage sludge start to degrade and some components start to transform(Shao et al. 2008) . Around 4.82mg weight loss as a results from degraded bonds. Meanwhile, 2.00mg approximately 11.19% mass loss when this sample are approaching between 650 ° C to 1000 ° C. Further explanation on degradation of the sewage sludge will be cover on the DTG profiles.

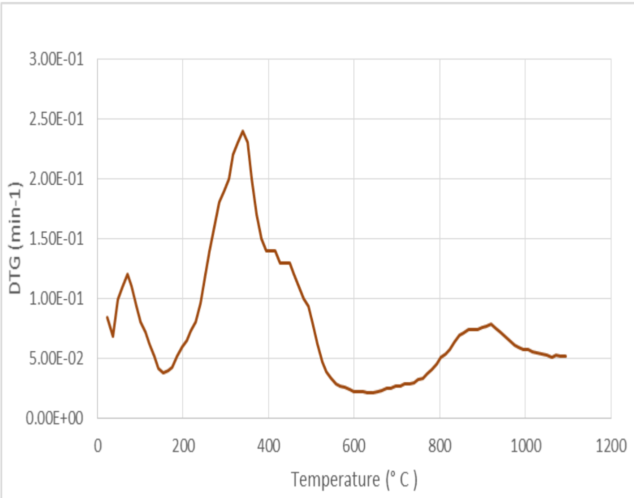


***Figure 3.1 DTG profiles of sludge degradation***

Figure 3.1 above shows the DTG profiles on degradation of sewage sludge. The DTG profiles above shows there are 2 peaks that are very significant to the sludge degradation and another 1 resulting a broad peak. The sludge degradation can be divided into 3 part where 1) moisture content, 2) volatile matter and 3) ash contents. The first peak of the DTG profiles presents the moisture content of the sludge start to vaporize (100-200° C) where it is important initiating steps in thermochemical conversion. The first peak also represent as the first decomposition of the sewage sludge around 100-200 ° C where moisture start to evaporate during that temperature (Alvarez et al. 2015). The second peaks presents the main DTG peaks at 350 ° C and ceases at temperature 550 ° C.

These stage where the volatile matter start to decompose this include biodegradable organic matter, aromatic hydrocarbons and aliphatic hydrocarbon. Wherby at this stage, the second decompositions start to take place around 300 ° C, whereas the decomposition between 360-525 ° C was related to proteins decompositions (Syed-Hassan et al. 2017). The last peak resulting of ash contents of the sewage sludge.

## 4. CONCLUSION

From the TGA and DTG tested onto Jasin Sewage Sludge Plant, at temperature 28.31 ° C about 4.31 % moisture being removed. Meanwhile, at temperature 334.87 ° C, around 24.44% volatile matter reduced and 11.19% ash contents eliminated at 887.59 ° C. By increasing the temperature of the pyrolysis, the sewage sludge percent of decompose are fluctuate depend of the degradation of the polymeric materials.

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