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Co-Gasification of Sewage Sludge with Coal – A Waste to Energy Conversion Approach

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Abstract

In the day-to-day life, the formation of waste becomes more and unavoidable. The disposal and management of sewage sludge becomes difficult to control. The thermo chemical conversion is most suited than the bio chemical as the retention time and volume of final waste are very minimum comparatively and also non uniformity in the structure makes the biochemical conversion bit difficult one. Among the thermo chemical conversion processes, the gasification holds good as the producer gas will have only non-toxic elements. Co gasification of sewage sludge with coal improves the energy recovery and makes it practically feasible one. In this work, TGA analysis were made for two different samples (raw sewage sludge, mixer of coal and sewage sludge) and thermal kinetics were studied for observing the suitability. The co-gasification of sewage sludge and coal was studied through operating the downdraft gasifier for different conditions

1.0 INTRODUCTION

Recently, sewage sludge has particularly become an important problem all over the world because of its harmful impacts on the environment and living beings. It should be converted to combustible gas or useful energy in order to remove all its negative effects and to contribute to a significant portion of the power generation. Because of its origin, sewage sludge contains a significant organic fraction with good potential for energy recovery. The thermal treatment of wastes has become more attractive than their disposal, by allowing not only reduction of their volume but also energy recovery. Several technologies have been extensively investigated and reviewed in the recent literature, including combustion, co-combustion, gasification and pyrolysis. Identifying alternative renewable sources of fuel and innovative energy production methods, which are potentially carbon neutral, has received increased interest during the latest decades. Energy generation from sewage sludge can be made practically feasible by several thermochemical conversions which may include co processing with other high energy content fuels such as coal. As an alternative to incineration, which produces hazardous air pollutants, gasification is a flexible process that generates a fuel gas that is suitable for feeding efficient gas engines and gas turbines, co-firing with coal in existing boilers, and the synthesis of biofuels. Having benefits of waste disposal and energy recovery, this proposed co gasification of coal and sewage sludge can be approached such a manner that hazardous and toxic elements produced out of disposal processes like land filling and incineration can be reduced as the producer gas will have only non-toxic elements. A main advantage of sewage sludge gasification is that a high-quality flammable gas may be obtained, so it can be directly used for electricity generation or for supporting the drying of sewage sludge and also may be employed as raw material in chemical synthesis processes

In this work, TGA analysis were made for two different samples (raw sewage sludge, mixer of coal and sewage sludge) and thermal kinetics were studied for observing the suitability by TG dynamic runs which was carried out at 5˚C/min in the temperature range 25–800˚C. For coal–sewage sludge blends, no interactions between the components were detected.

The Arrhenius kinetic parameters were calculated from the experimental results, considering the process as a series of consecutive first order reactions.

Correspondingly the co-gasification of sewage sludge and coal was studied through operating the downdraft gasifier for different conditions

2.1 PROXIMATE ANALYSIS OF SEWAGE SLUDGE

The proximate analysis is used to determine the distribution of products obtained When a fuel sample is heated under specified conditions. As defined by ASTM D 121, proximate analysis separates the products into four groups: (1) moisture, (2) volatile matter, consisting of gases and vapours driven off during pyrolysis, (3) fixed carbon, the non-volatile fraction, and (4) ash, the inorganic residue remaining after combustion. The method of experimenting proximate analysis was given below:

- ✓ The empty crucible is weighed by Electronic weighing machine and the mass is noted as m_1.
- ✓ The sample is placed in the crucible and total mass is found as m_2.
- ✓ The crucible with sample is placed inside the hot air oven with a temperature set of 110°C and retained in the same temperature for 10 minute.
- ✓ The crucible with sample is taken out and cooled to room temperature and the new mass is observed as m_3.
- ✓ The crucible with sample is closed tightly with the lid and placed inside the muffle furnace then it is heated to a temperature of 600°C.
- ✓ After that, it was taken out and cooled to room temperature in closed condition, and then the lid is removed, mass is noted as m_4.

- ✓ The same crucible with sample is again placed in the muffle furnace with open condition and heated to a temperature of 900°C.
- ✓ After reaching 900°C, the crucible is taken out and cooled to room temperature, the mass is observed as m_5.

The difference in masses will be calculated and then the proximate values will be calculated.

Table No 2.1: Proximate analysis of sewage sludge.

Proximate Analysis			
Moisture	Volatile	Fixed Carbon	Ash
9.7	33.4	9.5	47.4

2.2 ULTIMATE ANALYSIS OF SEWAGE SLUDGE

Table No 2.2: Ultimate analysis of sewage sludge.

Ultimate Analysis					
S	H	C	N	O_2	Cl
0.5	6.2	12.7	3.1	16.4	0.6

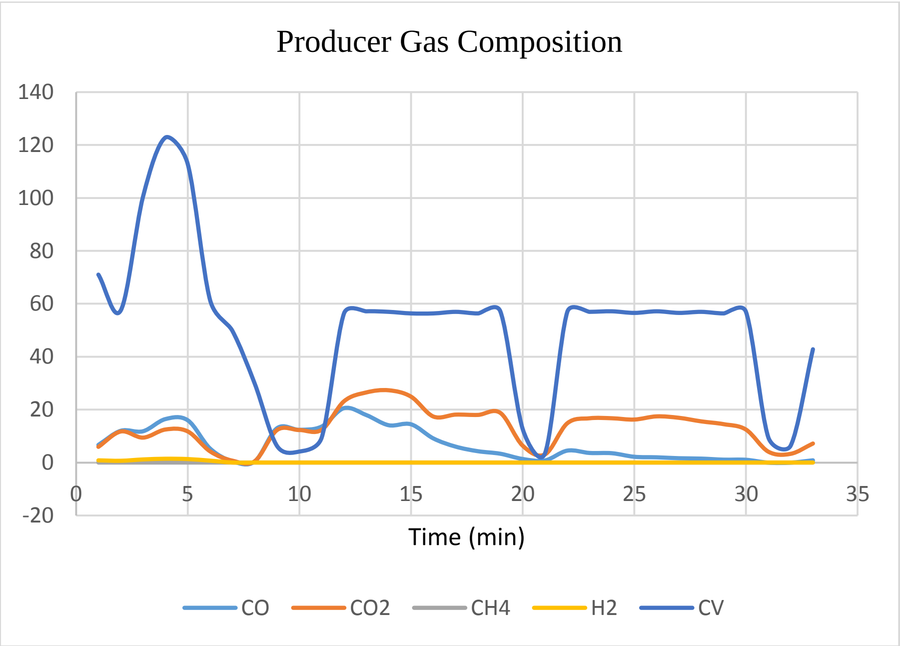
2.3 TESTING OF GASIFIER

The results were obtained through gas analyzer for the selected sewage sludge sample which is fed into the gasifier of downdraft type. The experimental data are given below:

Table No 2.3: Experimental data of gasification of sewage sludge.

TIME (Min)	CO	CO_2	CH_4	H_2	CV
1	6.6	5.9	0	0.8	70.9
2	12.0	11.9	0	0.7	57.4
3	11.8	9.4	0	1.2	100.4
4	16.4	12.0	0	1.5	122.7
5	15.9	11.8	0	1.3	112.8
6	5.3	4.2	0	0.7	61.4
7	0.5	0.6	0	0	49.7

8	0.4	0.4	0	0	29.8
9	12.8	12.2	0	0	6.2
10	12.3	12.3	0	0	4.1
11	13.6	12.3	0	0	9.4
12	20.5	23.2	0	0	56.3
13	17.9	26.5	0	0	57.1
14	14.1	27.3	0	0	56.9
15	14.4	24.6	0	0	56.3
16	9.1	17.2	0	0	56.3
17	6.0	18.4	0	0	56.9
18	4.3	18.4	0	0	56.3
19	3.3	18.0	0	0	57.1
20	1.3	6.3	0	0	12.9
21	0.8	3.0	0	0	3.4
22	4.5	14.8	0	0	56.9



3.1. THERMOGRAVIMETRIC ANALYSIS (TGA)

Thermogravimetric analysis (TGA) is a thermal analysis technique which measures the amount and rate of change in the weight of a material as a function of temperature or time in a controlled atmosphere. TGA measurements are used primarily to determine the composition of materials and to predict their thermal stability up to elevated temperatures. However, with proper experimental procedures, additional information about the kinetics of decomposition and in-use lifetime predictions can be obtained. Traditionally, isothermal and constant heating rate thermo gravimetric analysis have been used to obtain kinetic information with the constant heating rate method developed by Flynn and Wall being preferred because it requires less experimental time. However, the Flynn and Wall method is limited to well-resolved single step decompositions and first order kinetics. High resolution TGA, a new approach developed and patented by TA Instruments, provides an alternative not only for improving the separation (resolution) of overlapping decomposition peaks, but also provides a means for determining the kinetic parameters for more complex decompositions. High-resolution TGA is based on varying (slowing) the heating rate during decomposition regions and consists of a collection of heating algorithms which employ both historical algorithms namely, constant reaction rate and stepwise isothermal, as well as a novel method, dynamic heating rate.

3.2 STUDY OF THERMAL KINETICS

The sewage sludge is analysed for its thermal degradation by using Thermo gravimetric analyzer. Two combinations of sewage sludge were selected. One was pure sewage sludge and another one was equally mixed sewage sludge and coal. The data arrived from the TGA were given below for the two samples respectively:

Table No 3.1: Testing specifications of TGA

TGA Instrument Used	TGA 4000 perkin elmer
Atmosphere	Oxygen,20ml/min
Temp range	35-800 deg
Heating rate	5 deg/min

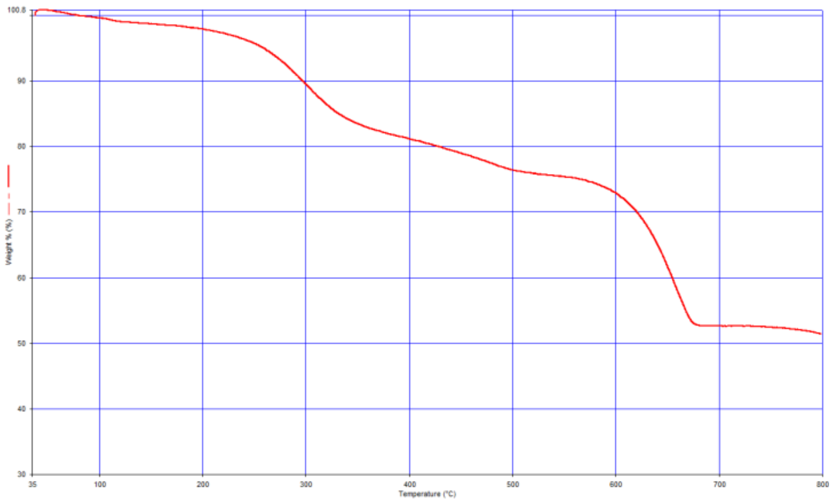


Figure No:3.2 Weight % vs Temperature for Sample A

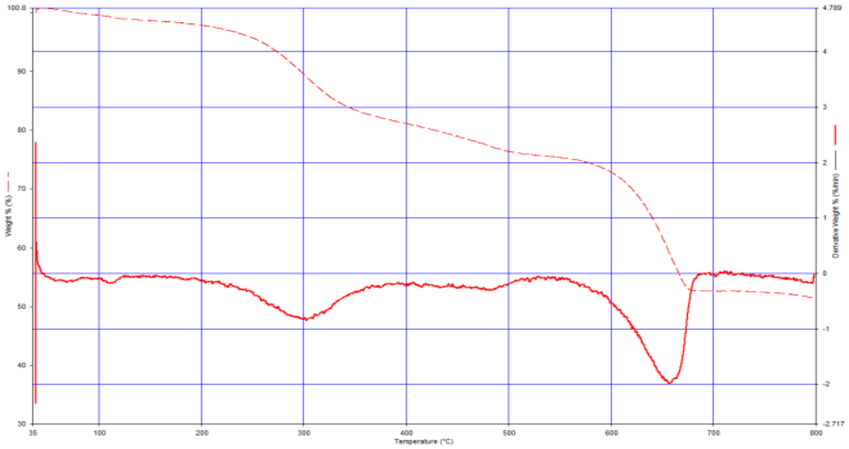


Figure No:3.3 *Derivative weight loss curve for Sample A*

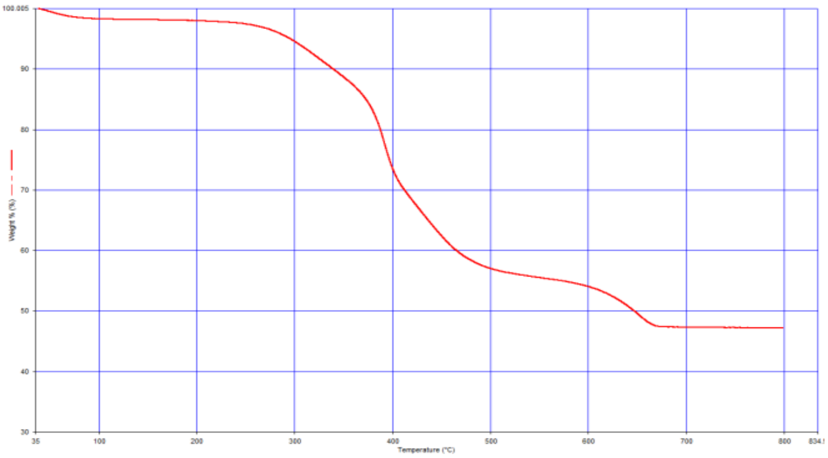


Figure No:3.4 *Weight % vs Temperature for Sample B*

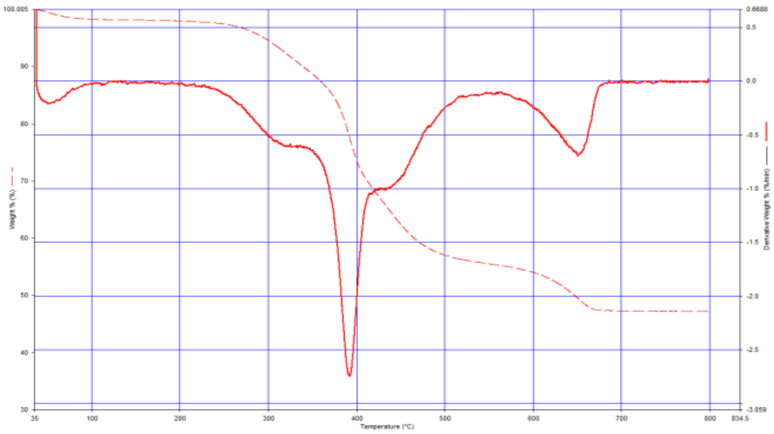


Figure No:3.5 *Derivative weight loss curve for Sample B*

The above graphs were obtained directly from the computer interface of TGA equipment. The data arrived per minute were used for the kinetic modelling of the samples. The sample A refers to the pure sewage sludge where as the sample B refered for the equally mixed coal and sewage sludge.

4.1 RESULTS

- The ash percentage in the raw dried sewage sample was found as around 40-50%.
- The producer gas enough calorific value and composition for better efficiency.
- From the TGA, it is observed that the coal mixed sewage sludge has comparatively better thermal degradation property than the pure sewage sludge.
- The DSC experiments showed that the sewage sludge can be gasified along with coal.
- The first order reaction is assumed in the kinetic study of thermal degradation of sewage sludge.
- The activation energy and Arrhenius constant for each zone were calculated.

5.1 CONCLUSIONS

- Firstly, the gasifier can be constructed and fed with wastes and coal. The producer gas, with minor treatment, can be fed to the thermal power stations.
- Power stations in cases where the lignite quality is very poor and outside the required limits. By these means, significant amounts of petroleum oil can be saved or substituted. Thus resulting in great capital savings.
- The increasing costs of conventional waste management and disposal options and the trend, in most developed countries as well developing countries, to divert an increasing fraction of mixed organic waste materials from landfill disposal, for environmental and legislative reasons, will make the investment in waste to power projects increasingly attractive.
- Co-gasification involving solid waste and coal does not appear to be of significant interest worldwide. There are still a few technical matters that have to be solved, such as the cost-effective syngas cleaning and the gas turbine modifications for utilizing the syngas. In general, the costs of a process decrease as more units are built and experience is gained. A learning factor may be observed, which is a fixed percentage reduction in cost as the cumulative installation of plants doubling.
- For thermal power stations like Tuticorin Thermal Power Stations, the Co-gasification will be suited well when it is planned for macro scale providing continuous sewage sludge supply.
- The burden on industries and municipalities will be reduced significantly if the sewage sludge can be economically co-gasified with coal through technology advancements.

5.2 FUTURE SCOPE

- The proposed co-gasification method will find economic measures in future which will definitely witness the higher degree of stringent regulations in the sewage sludge disposal and scarcity in coal supply. In that context, energy generating method of waste disposal will be focused in a macro scale.