

PYROLYSIS OF SEWAGE SLUDGE FOR THE PRODUCTION OF LOW COST RENEWABLE ENERGY SOURCE

Dr Syed Amjad Ahmad^{*1}, Dr Muhammad Yasar Javaid², Imran Ali Channa³,
Ubaidullah Khan⁴, Aijaz Ali Dahri⁵

^{*1}NFC Institute of Engineering and Fertilizers, Research, Faisalabad, Pakistan.

²Department of Mechanical Engineering, and Technology Govt College University Faisalabad, Pakistan.

^{3,4,5}Department of Civil Engineering, Quaid-e-Awam University of Engineering, Science & Technology Nawabshah, Sindh, Pakistan.

^{*1}samjadahmad67@yahoo.com , ²yasarjavaid@gcuf.edu.pk.

³engrimranalichanna@gmail.com , ⁴ubaidullahkhan@quest.edu.pk ,

⁵aijazdahri@quest.edu.pk



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Corresponding Author: *

Dr Syed Amjad Ahmad*

Abstract

Pyrolysis of municipal sewage sludge attracts the whole world researchers due to its ever increasing volume and low cost input for energy production as a renewable energy source. Due to the high pricing of fossil fuel and forecast for decreasing of its resources in the middle of this century compelled the researchers to search out its alternate of whom the cost is around the cost of fossil fuel or lower than it and is environmental friendly. Fossil fuel also produces greenhouse gases that affect the environment and create global warming therefore its alternatives are essentially desired. Now a day's biomass, solar, wind nuclear, hydro, geothermal hydrogen & fuel cells, gravitational, geothermal, human-powered, ocean & wave / tidal energy etc. are the main sources for the development of low cost energy production at the cost of waning the production of CO₂. As the municipal sewage sludge is a main constituent of biomass and is the only one that is freely available where lives exist. Now a day's its production is increasing day by day due to increase of urbanization and industrialization. Pyrolysis conditions, like heating rate and final pyrolysis temperature, were varied so that their influence on the characteristics of the resulting gases, liquids and solid residues could be studied. It was found that increasing the pyrolysis temperature decreases the solid fraction yield and increases the gas fraction yield while that of the liquid fraction remains almost constant. Therefore, the effect of the heating rate was found to be important at low final pyrolysis temperatures and the pyrolysis conditions. All the solid products obtained were of a basic nature and highly macro porous, the meso- and micro-pore volumes being relatively low. Pyrolysis gas contains N₂, O₂, H₂, CO, CH₄, CO₂, and a little amount of other hydrocarbons as some highly efficient fuel gases. GC, TCD and GC FID were used to find the percentage of these in pyrolysis gas. During this Pyrolysis process tar and char is also generated. Tar was also collected for analysis of different compounds present in it using impinger train as per EU protocol.

INTRODUCTION

In 2008 the annual world primary energy consumption was estimated as 11,295 million tons of oil equivalent (MTOE). Fossil fuels accounted for 88% of the primary energy consumption, with shares of oil (35%), coal (29%) and natural gas (24%) as the major fuels, while nuclear energy and hydroelectricity account for 5% and 6% of the total primary energy consumption, respectively [1]. At present, biomass share in the world's total primary energy consumption is about 12%, it is estimated that biomass share will be increased to near 15% within a decade in developed countries. Given the current technological progress, potential reserves, and increased exploitation of newer unconventional reserves (e.g. for natural gas), it is highly probable that fossil fuels will continue to be available at low cost for a considerable period of time; albeit with the variations in the security of supply arising from geopolitical developments, from time to time [2,3]. Unfortunately, the potential threat of global climate change has increased, and for a major part, this has been attributed to greenhouse gas emissions from fossil fuel usage [4]. The associated climatic change projections could have major consequences for nature

as well as human systems [5], which creates uncertainty regarding the sustainability of current fossil fuel use, not only in relation to the finiteness of the resource, but also on the negative effects of CO₂ emissions. Fossil fuels are the largest contributor of greenhouse gases (GHGs) to the biosphere, and in 2006 associated CO₂ emissions were 29 Gtons [6]. It is estimated that natural processes remove only about 12 Gtons, therefore, compatible mitigation strategies are required to neutralize the excess CO₂ [7]. With the increase in anthropogenic GHGs emissions, mainly due to large scale use of fossil fuels for transport, electricity and thermal energy generation, it has become increasingly important to develop abatement techniques and adopt policies to minimize impacts of global warming. The Kyoto Protocol of 1997 called for a 5.2% reduction in GHGs emissions worldwide from 1990 values [8]. To meet the agreed target, a selection of a range of effective technologies, including chemical and biological CO₂ mitigation possibilities, has been a focus of research. The overall implication is therefore a need for enhancement of global strategies for energy security and mitigation of CO₂ - energy

related emissions, for which the salient strategies include, inter alia, the need for: increased energy efficiency (i.e. decreasing energy use per unit of product, process or service); increased use of clean fossil energy (i.e. use of fossil fuels coupled with CO₂ separation from flue gases and injection into underground reservoir for gradual release), and; increased use of renewable energy (i.e. development of CO₂-neutral energy resources). Given the necessary CO₂ emission targets, and the potential of each of the out lined strategies to the timely reduction of CO₂ emissions to 'safe levels', it has been argued that the three outlined strategies will have to be employed in order to tackle the progression of climatic change [9].

Another main environmental problem which is faced by every country is the safe disposal of sewage sludge produced by waste water treatment plants. As the transfer of population from small cities to big cities increases due to eminence facilities i.e. better job opportunities, high-quality medical and education facilities etc. are easily accessible in big cities, this transfer of population increases the load on waste water treatment system. Due to this reason production of sewage sludge increases day by day and its safe disposal became a big problem in many industrialized countries. Most of the pollutants, heavy metals, etc. removed in

decontamination processes reappear in the sewage sludge, which, therefore, becomes highly concentrated in contaminants. To deal with this waste is, of course, complicated and inevitably gives rise to collateral pollution. Thus, the agricultural use of sewage sludge, land filling incineration and sea dumping are the most common methods of get rid of sewage sludge [10], does not completely remove the risk of contamination. Despite legal control restrictions, intensive use of sewage sludge in agriculture gives rise to an increase in the concentration of heavy metals in the soils [11]. Disposal by land filling requires a lot of space and the soil has to be sealed adequately to prevent the leaching of harmful compounds. Finally, expensive devices have to be implemented in the incineration plants in order to prevent the release of gases and solid pollutants. In view of these drawbacks the pyrolysis of sewage sludge is currently being investigated as an alternative to the problem of sewage sludge disposal. Pyrolysis presents certain advantages over the other methods. The volume of solid residue is drastically reduced; the heavy metals present in the carbonaceous matrix are relatively resistant to natural lixiviation [12 and 13], it gives rise to gases and oils with a high energetic value which could be used as potential fuels. Pyrolysis is carried out at lower temperatures than in the case

of incineration, which limits the amount of pollutants released in the pyrolysis gases, as the process is carried out in the absence of air no dioxins are produced [14]. The pyrolysis of sewage sludge is, not, however, without its drawbacks. Thus, the volume of reduction of the solid residues is lower than in the case of incineration, the combustion of the fuel gases and/or liquids produced by pyrolysis gives rise to gases, which contain harmful compounds. The technology for carrying out the pyrolysis is less developed than in the case of incineration. In support of pyrolysis, however, is the high number of reports available that deal with different aspects of sewage sludge pyrolysis. For example, rotary kilns [15], fluidized beds [13, 16 and 17] and flash pyrolysis [18] have been investigated as possible ways of treating sewage sludge. The economic aspects of different pyrolysis processes have been studied by Kasakura and Hiraoka [19]. Pyrolysis of sewage sludge under different conditions aimed at studying the pyrolysis mechanism [12, 20 -22] and/or the

characteristics of the gases, oils and tars and solid residues has also been studied [12, 18, 21, 23 - 25]. The aim of the present work was the study of different pyrolysis conditions (pyrolysis temperature , heating rate and steam feeding) for the production of high quality char and large amount of syn-gas by processing sewage sludge from urban wastewater treatment plant.

Experimentation

Materials

Sewage sludge was collected from the waste water treatment plant, Gwangju city of South Korea as the biomass for the experiments. It contained more than 80 % of moisture. The proximate analysis and ultimate analysis of the dewatered sludge was given in table 1. Sewage sludge was dried in lab electric furnace/oven for 24hours at 105°C to lowering its moisture contents nearly up to 10 %.The samples were reduced to small particle size of 2~3mm range for experimentation.

Table 1. Proximate analysis and Ultimate Analysis of Dewatered Sludge

Description		Dewatered sludge
Proximate analysis	Moisture	80.30
	Organic	Wet basis 11.70

(Wt %)	compound contain	Dry basis	55.90
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Ultimate analysis (Wt %)	Ash	9.20
	C	14.40
	H	10.50
	O	2.65
	N	25.20
	S	2.78
	Higher heating value (kcal/kg)	3857.10

Experimental Set-up

Pyrolysis of the sample was carried out in a stainless-steel pipe of 85mm and 500mm in diameter and length respectively. Heating with the electric furnace (CLF-T1320, CERINHITEC) enabled to control temperature up to 1000 °C (Figure 1). Ceramic distributors were placed in two places at the lower part within the reactor to keep the flow of fluids uniformly. Samples were placed in the basket with stainless-steel mesh at the bottom. The continuous measurement of temperature of furnace, sewage sludge sample and outside gases in the reactor and steam generator were made possible with the thermocouple (KtypeO.D.: 3mm) separately with the data analysis device (Hydra data logger 2625A, FLUKE). A fixed quantity of argon gas was injected from the two places of the lower portion of the reactor for uniform flow to the sample. The temperature could be maintained up to -30°C. Steam was provided, with a steam

generator installed on the supply line. The steam generator consisted of a stainless-steel pipe of 17.5mm and 350mm in diameter and length respectively, has an inserted heating stick whose temperature can be internally kept up to 250 °C. The amount of steam was controlled with the water syringe pump (KDS 100, KDScientific, USA). Wet gas meter (SHINAGWA CORPORATION, measuring range 1L/rev, min 2 ~ 600L/h, maximum working pressure 9.8 KPa model W-NK-1A, made of Japan) was used for the measurement of gas flow all are shown in Figure 1. GC TCD and GC FID are used for the measurement of the different syngas produced during the pyrolysis process.

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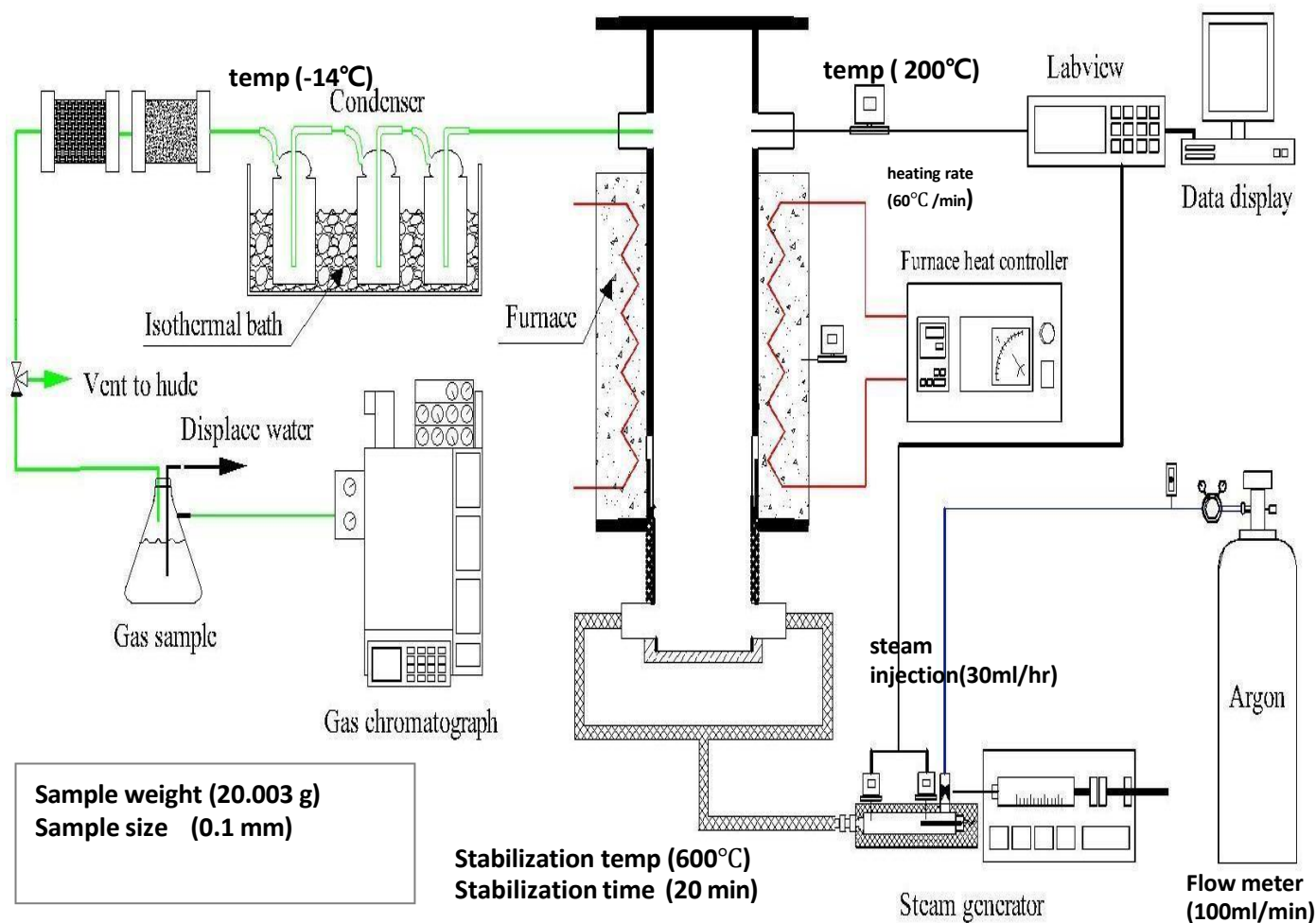


Figure 1. Experimental set up (TOKYORIKAIKAI Co. Ltd, Japan)

Experimental Method

The Pyrolysis of the sewage sludge was carried out in a vertical stainless- steel reactor. To carry out these pyrolysis

experiments sample weight of 20g and particle size of 2~3mm was used for each test. To remove the oxygen and nitrogen present in the reactor, argon injection was started 30 min before the startup of the experiment for purging of these unwanted gases. In order to ensure an inert environment during the experiment, a 100 ml/min of argon flow rate was fixed in the reactor. Different pyrolysis temperatures (500,600,700,800,900°C) (Table 2). and heating rates of 10, 20, 30, 40°C/min and different holding time 10, 20, 30, min were studied. The pyrolysis products were swept out of the reactor and passed through impinger train as per EU protocol.

The reactor could be operated at a fast heating rate mode or slow heating rate mode. The volatiles evolved from the sample passed through the six consecutive impingers placed in a water bath and also in the ice bath 1st five impingers contain Isopropanol. The aqueous friction recovered in these impingers showed a dark color. This friction was separated from the organic friction by decantation, while the organic friction dissolved in the Isopropanol was collected by evaporating the solvent at 40°C. The yield of the solid and oil fractions were calculated on a dry basis from the weight of each fraction, while the gas yield was evaluated by the difference of the above two.

Thermocouples are used for the accurate monitoring of temperature at different points like, sewage sludge sample temperature, inside reactor gas temperature, steam injection temperature, furnace temperature, water bath temperature, ice bath temperature and atmospheric temperature. The non-condensable gases were collected in tedlar sampling bags of 1L volume with a polypropylene fitting for sampling and analysis from GC-TCD/GC-FID.

Pyrolysis of the sample was carried out in an argon supplied fixed bed reactor with an electrical furnace. The reactor could be operated at a fast heating rate mode or at slow heating rate mode, as per requirement of the study. The nascent char would be self-gasified by the reactive species (e.g. H₂O and CO₂) in the volatiles [26], including the moisture contained in the biomass particles fed into the reactor. It has been observed that when furnace temperature reaches up to 288°C (furnace wall temperature) at 10°C/min and at the same time sludge sample reached up to a temperature of 150°C and at this temperature gasification of the sludge sample started because we observed the fumes in the 1st impinger. It had been observed that there was a lot of difference between the sludge sample temperature and furnace temperature (i.e more than

100°C) which showed that furnace temperature did not show the temperature of the sludge. Therefore prior assumptions/suppositions about sewage

sludge behavior were wrong. This result showed that at 150°C of sludge temperature gasification started between 288~300°C of furnace temperature.

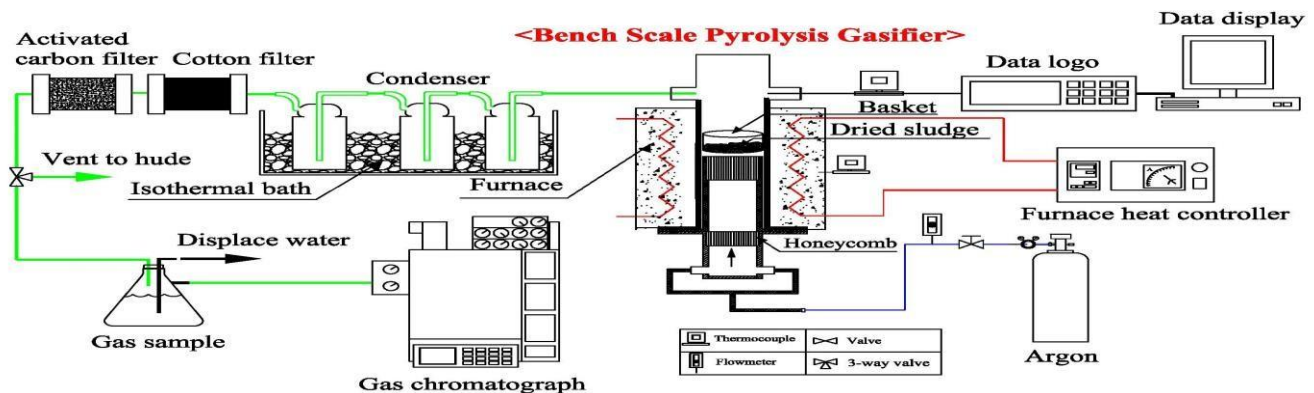


Figure 2.

The thermocouples were used for measuring exact temperature of sludge and its behavior against temperature not the wall temperature of the furnace/reactor. It was observed that there was a lot of difference between furnace temperature and the sludge temperature. The results showed that sludge temperature was round about half of the furnace temperature.

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