

**COMBUSTION AND EMISSION CHARACTERISTICS OF MUNICIPAL SEWAGE SLUDGE IN OXYGEN-ENRICHED BUBBLING FLUIDIZED BED****Rajesh Kumar****Department of Mechanical Engineering, Birla Institute of Technology & Science, Pilani, Pilani Campus, Rajasthan, India. E-mail: rajesh.narota@gmail.com, Tel: (+91) 9465837776, *Corresponding Author.***Ravi Inder Singh***Department of Mechanical Engineering, Birla Institute of Technology & Science, Pilani, Pilani Campus, Rajasthan, India
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Abstract: Municipal sewage sludge (MSS) disposal is one of the most complex environmental problem for India: as landfilling takes up a lots of land and contaminates, dumping into sea is harmful and some of MSS products are not suitable for the agriculture. Incineration is one of the promising method which utilized the heating value of the MSS to produce energy and reduced the sludge volume to small stabilized ash. Fluidized bed is used extensively for the MSS incineration worldwide. Oxygen-enriched fluidized bed combustion is the one of latest method to control carbon dioxide. In the present work, the combustion and emission characteristic of municipal sewage sludge is carefully monitored and experimental measurements were obtained in a 20kW bubbling fluidized bed (BFB) combustor under variable oxygen-enriched conditions. Temperature profile and emission in flue gas is studied at a suitable range of combustion temperature. The short fluidized bed combustor of 1.8 m in length is made from financial grant obtained from DST New Delhi India.

Keywords: *Municipal sewage sludge (MSS), Fluidized bed, Oxygen-enriched, Combustion, Emission.*

I. INTRODUCTION

India being a developing nation is currently facing many challenges and municipal sewage sludge (MSS) disposal is one of them. As the “Govt. of India” launching some scheme like “Clean India” to mitigate such a problem but the biggest question that laid in front of us is selection of the appropriate method for the disposal. The main disposal methods for the MSS are landfill, dumping in sea, recycling in agriculture, and incinerations. Incinerations is one of the significant method which give more advantage then the other methods. Werther et al. [1] discussed the three groups of thermal processing of sewage sludge like; mono combustion incineration, co-combustion and alternative process. The volume of the waste is reduced by the incineration. Neha et al. [2] presented the physical and chemical characteristics of municipal solid waste in Indian cities. It observed the possibility to produce clean energy from the incineration of MSS by using the advance combustion technologies like oxy-fired or oxygen-enriched fluidized bed combustor.

Fluidized bed technology is capable of burning different varieties of low carbon fuels with low emissions [3]. India, have been involved in the development of FBC systems since 1975. Han et al. [4] analyzed the combustion characteristics of sewage sludge in a fluidized bed combustor and concluded that MSS having moisture content less than 40% can stably burn without any auxiliary fuel input. Zhu et al. [5] proposed and investigated a new method of sewage sludge incineration

which is divided into two stages and gives the higher combustion efficiency. Jang at al. [6] compared the combustion performance of the sewage sludge in air and oxy-fuel circulating fluidized bed. It was observed that the range of 21% to 25% of oxy-combustion is more beneficial to apply carbon capture and storage technology (CCS) technology.

The objective of this work is to demonstrate the feasibility of bubbling fluidized bed combustor as a clean technology for burning the MSS under oxygen-enriched condition. The combustion and emission characteristic of MSS is carefully monitored and experimental measurements were obtained in a 20kW oxygen-enriched bubbling fluidized bed (BFB). Temperature profile and emission in flue gas is studied at a suitable range of combustion temperature.

TABLE I. PROPERTIES OF MSS

Properties of MSS	
Proximate Analysis	Wt. %
Moisture	2
Volatile Matter	24
Ash	58
Fixed carbon	4.1
Ultimate Analysis	Wt. %
Carbon	13
Hydrogen	1.8
Nitrogen	1.3
Sulphur	--
Oxygen	14
GCV	3.5 MJ/kg

II. METHODOLOGY

A. Fuel property

The fuel used in this study is MSS which is collected from the sewage treatment plant Bits-pilani, pilani campus in dry form. The proximate and ultimate analyses of MSS are shown in the Table 1. The MSS have the 3.5 MJ/kg gross calorific value. Sulphur concentration in MSS was not found.

B. Experimental setup and procedure

The work described in this paper is performed on a 1.8 m long square bubbling fluidized bed combustor is shown in Fig. 1. This combustor having two cyclones (C1 & C2), induced

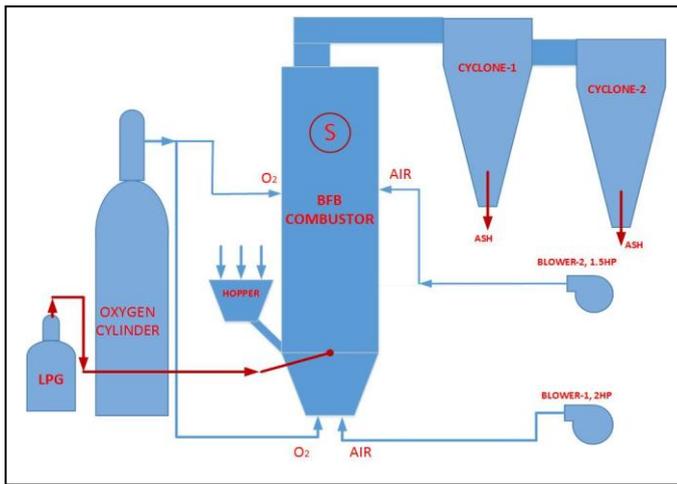


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fan, flue gas cooler and stack. The tests are performed on both enriched air-combustion mode and on oxygen-enriched combustion mode. The air and oxygen for the fluidization is entered through the distributor nozzle from the bottom side into the bed of the combustor and passes upward into the fluidized bed. The dry MSS for the combustion is entered through the hopper in dry form into the splash zone of the combustor. Temperature of bed, splash zone, and freeboard is measured at different height for each test when steady state is reached. The net thermal capacity of this system is below 20 kW. The flue gas concentration is measured into the freeboard through port “S” by employing Testo-350 portable gas analyzer.

Fig. 1. Experimental Setup schematic



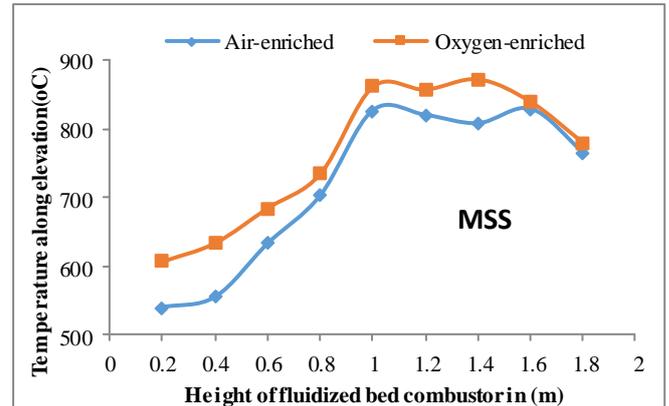
III. RESULTS AND DISCUSSIONS

A tests are performed on a bubbling fluidized bed when steady state is reached to investigate the effect of MSS (under both air-fired and oxygen-enriched condition) on the performance of a fluidized combustor and gas emission. The oxygen enhanced up to 20% and a constant fuel feed rate of approximately 18 kg/hr was maintained throughout the experiments.

A. Temperature profile

Fig. 2 presents the temperature profile for the air-fired and oxygen-enriched condition along the height of the combustor, during combustion of MSS at steady state condition. An increase in the temperature is noticed just above the bed, where the fuel is entered into the combustor. The combustion rate at this zone is higher cause of volatile release in this zone whereas the combustion rate in the bed is lower because the bed is operated at the less fuel. In case of air-fired, an increase in temperature is observed in-between 1.4m to 1.6m, where the biomass is burned in the freeboard. Further the temperature falls dramatically at the top of the combustor at 1.8m. The probable reasons for the same are due to increase in the velocity at that point due to the ID fan etc.

Fig. 2. Combustion temperature along the elevation for dry MSS at 18 kg/hr feed rate under steady state.



As the oxygen concentration increases (upto 20% or above) the combustion characteristics change slightly with respect to temperature. Fig. 2 shows that with higher O₂ concentration, temperature increases sharply above the bed. It observes that with increase in oxygen concentration the combustion rate is increased, which leads to complete combustion.

B. Flue gas emission

NO_x concentration for MSS under steady state, air-fired and oxygen-enriched condition is shown in Fig. 3 at 18 kg/hr feed rate. NO_x production is depending on the nitrogen contents in the fuels and temperature rise. MSS on dray basis has very less nitrogen content produced less NO_x. Result shows that with increase in oxygen concentration, inside the combustor the combustion rate increased which further increases the temperature. NO_x production is directly proportional to the temperature rise. Fig. 3 shows increased in NO_x under oxygen-enriched condition.

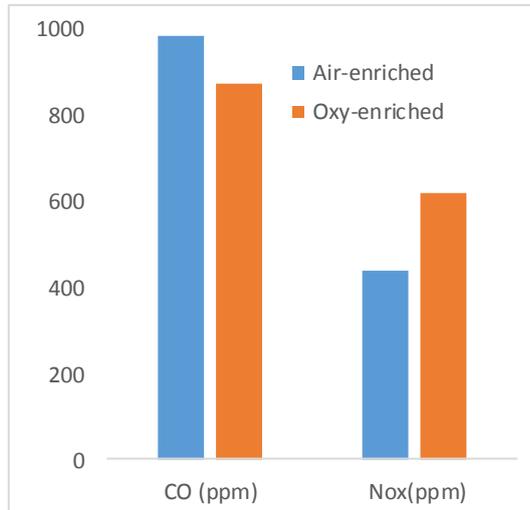
Fig. 3 reports the CO concentration for MSS under steady state, air-fired and oxygen-enriched condition at 18 kg/hr feed rate. It is observed from the figure that the amount of the carbon monoxide decreases with increase in the oxygen concentration. Because at steady state the amount of the fuel is stable and the oxygen content are higher which increase the combustion rate of the fuel.



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Fig. 3. Gas emission measured in freeboard at a feed rate of 18 kh/hr.



IV. CONCLUSIONS

An experimental study of the oxygen-enriched bubbling fluidized bed with MSS has been carried out to investigate the combustion temperature and flue gas emission under air-fired and oxygen-enriched condition. It observed that the MSS on dry basis combusted successfully in bubbling fluidized bed under both air-enriched or oxygen-enriched conditions. The burnout inside the combustor is improved with increase of oxygen concentration inside the combustor. When steady state is reached the amount of the fuel supplied is stable. With the

increase in combustion rate the concentration of CO reduces gradually and NO_x concentration increases.

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