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ScienceDirect

Procedia Environmental Sciences 35 (2016) 513 – 527

Procedia Environmental Sciences

International Conference on Solid Waste Management, 5IconSWM 2015

Kinetics of Pyrolysis of Mixed Municipal Solid Waste- A Review

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Abstract

Municipal solid waste management is one of the major challenges faced by most of the developing countries like India. The scarcity of land due to large population and increasing waste production due to urbanization impose a challenge to find innovative methods for waste disposal. Thermal treatment is seen as an emerging technology which can help in reducing the volume of the waste and also extract energy and value added products during processing of the waste. However, the raw material mostly has low calorific value which causes problem for its thermal treatment. Pyrolysis, combustion and gasification are the major thermal treatment processes. Pyrolysis, found more promising than other processes, is discussed in this paperin regards to its kinetics and reaction conditions and products formed to understand and further develop the technology. Any improvement in the treatment processes requires an understanding of the fundamentals of the reactions specific to the waste being treated. It is concluded that suitable combination of reaction conditions along with reactor design needs to be formulated once the process kinetics for the treatment of mixed municipal solid waste during pyrolysis is estimated.

Peer-review under responsibility of the organizing committee of 5IconSWM 2015
Keywords:Pyrolysis, reaction kinetics, mixed solid waste, characterization;

1. Introduction

The solid waste is generated as a byproduct of most of the socio-economic activities. The waste generated from different sectors like commercial, institutional, domestic is included in municipal solid waste (MSW). The urbanization, industrialization and increase in population directly affect the MSW generated (Jain and Sharma, 2011). Globally, the volume of waste generated from urban centers of the world is around 1,300 million tonnes per year (1.2 kg/capita/day) which is expected to rise to 2,200 million tonnes per year by 2025. The waste generated

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Peer-review under responsibility of the organizing committee of 5IconSWM 2015
doi:10.1016/j.proenv.2016.07.036

from South and East Asia represents 33% of the world's total quantity. It is anticipated that the MSW generation rate in Asia will reach to 1.8 million tonnes /day by 2025 (Srivastava et al., 2014).

For India MSW generation ranges between 0.3 kg/capita/day and 0.6 kg/capita/day, with the annual volumetric increase in MSW generation is estimated to be 1.33 % per capita. Table 1 summarizes the per capita waste generation in different populated cities of India along with the solid waste treatment techniques employed by the municipalities in corresponding cities.

The MSW generated is rarely treated in India. 90% of waste is unscientifically dumped openly or landfilled creating health and environmental issues (Sharholy et al., 2008). Landfills are rather a temporary storage place, and hence waste needs to be treated to convert it into valuable product, that is waste to product (WtP) or waste to energy (WtE). Waste to energy processes such as biological treatment or thermal treatment utilize the energy potential in waste to reduce CO_2 and other pollutants emission to atmosphere (Helsen and Bosmans, 2010). Biological treatments have an advantage of reducing the mass and volume of waste, yet they take time to decompose products which may extend from few months to years. Also, bio treatment is low temperatures treatment, which does not destroy the pathogens completely. The other Waste to energy techniques are thermal techniques such as incineration, gasification and pyrolysis. The thermal treatment plants in India have not performed well so far in India, yet this work focuses on thermal treatment owing to its advantage over biological treatment and landfilling.

Table 1: Waste generation & handling techniques in different populated cities of India per capita(Jain and Sharma, 2011), (KharvelAnnepu, 12)

Name of city	Population (as per 2001 census)	Waste generated (kg/capita/day)	Available waste treatment technique and capacity of plant (as per 2010)
Gangtok	29,354	0.44	Composting (50 TPD)
Daman	35,770	0.42	—
Jammu	369,959	0.58	—
Dehradun	426,674	0.31	426,674
Chandigarh	808,895	0.2	Composting, Biomethanation, RDF (500 TPD)
Bengaluru	4,302,326	0.39	Composting (450 TPD)
Chennai	4,343,645	0.62	Composting
Kolkata	4,572,876	0.58	Composting (700 TPD)
Delhi	10,306,876	0.58	Composting (825 TPD), biomethanation, RDF (1350 TPD)
Greater Mumbai	11,978,450	0.45	Composting (370 TPD)

2. Thermochemical processes

Thermal treatment of the solid waste reduces the mass by 70–80% and volume by 80–90% (Lombardi et al., 2015). The time required for treating the waste thermally takes only minutes or hours, and forms a stable odour free product, free of pathogens. Environmentally, thermal treatment is better than biological or landfills. Landfills emits methane (four times more effective greenhouse gas as compared to CO_2) during the anaerobic digestion of waste, while thermal treatment releases only CO_2 and other gases such as CO, methane having high calorific value is extracted for energy recovery(Shah, 2011). As stated by Sharholy et al., (2008) all waste to energy thermochemical techniques have been tried and tested in developed countries with positive results. These are yet to get off the ground in India largely because the financial viability and sustainability is still being tested.

The available technologies for thermochemical treatment of waste are pyrolysis, gasification, plasma gasification and incineration. Table 1 shows a schematic diagram of the products formed by thermally treating the waste by different techniques. Each of the technique is discussed in the following section.