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# SUSTAINABLE TECHNOLOGY FOR THE EFFECTIVE MANAGEMENT OF MUNICIPAL SOLID WASTE: PYROLYSIS

Environmental Science

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## ABSTRACT
Now a day's one of the major challenges faced by most of the developing countries as if India is the management of the municipal solid waste. The quantum of solid waste is increasing due to increase in population, activities and socio-economic conditions. It is a matter of concern that disposal of waste being non- biodegradable causing many problems resulting into environmental hazards. The scarcity of land impose a challenge to find novel methods for waste management. Thermal treatment is seen as an emerging technology this can reduce the volume of the waste and generates value added products from the municipal solid waste. Pyrolysis of solid waste is the most efficient technologies used to produce biofuels. The main area of focus of this paper is the investigate the pyrolysis of the collected municipal solid waste from dump yard. The calorific value of the gas and char at 600 $^0$C pyrolysed samples were observed to be 2050 and 4100 for paper waste and 2050 and 4450 for garden waste; at 650$^0$C it was found to be 1900 and 4356 for paper waste and 2100 and 4656 for garden waste samples.

## KEYWORDS
Pyrolysis, Municipal Solid Waste, Paper, Garden Waste, Char.

## INTRODUCTION
With an ever increasing population and rapid pace of urbanization, the country is facing a huge challenge of waste management. The volume of waste is projected to rise from the present 62 million tonnes to about 150 million tonnes by 2030. Indiscriminate dumping of garbage at the current rate without appropriate scientific treatment, would impose huge requirement of landfill area per year. This necessitates the importance of scientific solid waste management in today's context.

Current practices for municipal solid waste (MSW) disposal such as landfill and incineration poses a serious problem on the environment and health. Leachate generated from landfill is polluted liquid and consisted high nitrogen compounds, salts, heavy metal. Incineration generates dangerous gases such as carbon dioxide ($Co_2$), sulfur dioxide ($SO_2$), and oxides of nitrogen (NO and $NO_2$, together known as $NO_x$). Studies suggest that the Municipal Solid Wastes generated in India mostly consists of a large fraction (> 50%) of organic wastes. Unscientific disposal of organic waste produces greenhouse gas (GHG) emissions and other air pollutants. The ineffective processing of MSW also is the root cause of many diseases as the dumped landfills transform into Contamination Hubs for Pathogens, Bacteria and Viruses. The most commonly used processing "composting" also does not yield impactful economic returns for the entrepreneurs as it requires more land space, more labour, pasteurization for effective disinfection and has restricted utilization due to presence of heavy metals. During the rainy season managing composting becomes difficult due to the presence of excessive moisture.

India rivers have been polluting due to the improper solid waste management. The implementation of the thermal treatment plant (incinerator) in India was not successful due the high cost of the operation. The high moisture content of the waste and a poor technical expertise in maintaining the incinerators caused the failure of the incineration operation. Thus, moisture reduction is needed prior before goes for incineration. Therefore, the current waste management system adopted by incinerator to be made improvement based on effective energy recovery system.

The moisture contents must be decrease to 75% before subjecting to pyrolysis. The high heating value (HHV) of the MSW is a main impact on the cost of the operation. The implementation of the pyrolysis system can be reduced the total amount of MSW before buried in landfill. The MSW pyrolysis is one of the ideas that has become increasingly in recent years. It can prevent the formation acidic substances and reduce the amount of garbage before sending over to the landfill and save the transportation fuel.

The main goal is the production of energy from the organic fraction of the sludge, while affecting the environment as little as possible. However, the production of valuable chemical products gains increasing importance, besides the production of fuels. As thermal conversion process, pyrolysis has potential for sludge management, since it achieves up to 50% reduction of waste volume (Inge Velghe et al, 2013).

Pyrolysis is the thermochemical decomposition of organic material at high temperature and in absence of oxygen or inert gases atmosphere. Nowadays, pyrolysis is getting attention for its flexibility to generate a combination of solid, liquid and gaseous products in different proportions just by the variation of operating parameters such as temperature or heating rate. It also gives possibility to transforms materials of low-energy density into bio-fuels of high-energy density and recover higher value chemicals [Chowdhury et al, 2012, Kumar et al 2013]. One of the great advantages of this process is that many types of raw material can be used, including industrial and domestic residues. The fractions of MSW subjected to pyrolysis mainly include food waste, paper, cloth, plastics, and yard waste. It is then easy to understand the high variability of conditions and consequently of residues obtainable. Prerequisite for pyrolysis successful application is the appropriate choice of input materials and setting of optimal process conditions. For these reasons, suitability or unsuitability of selected types of waste and their mixtures for the pyrolysis process was verified by laboratory experiments many times with subsequent assessment of the quantity and quality of the individual products of pyrolysis [Srilatha et al, 2017].

## MATERIAL AND METHODS
**2.1 Municipal solid waste:** Municipal Solid Waste collected from the municipal dumping site located at Hyderabad, Telangana, India. The segregated sample is used for the carrying the pyrolysis experiment.

### 2.2 Characterization Techniques
The Proximate analysis, ultimate analysis were done using standard methods (Srilatha et al, 2017).

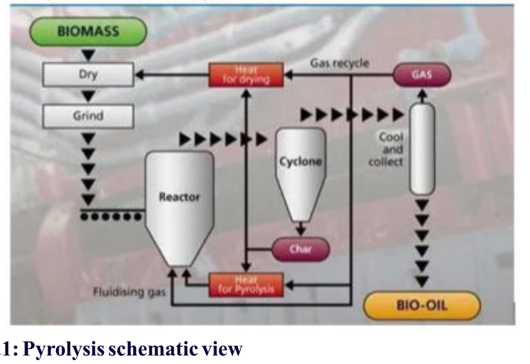


**Fig.1: Pyrolysis schematic view**

The following equations were used to calculate the yield of bio-oil, biochar, and gas.

$$\text{Yield of bio-oil (wt\%)} = (\text{weight of measuring cylinder with bio-oil}) - (\text{weight of empty measuring cylinder})/(\text{weight of feed}) \times 100$$

$$\text{Yield of bio-char (wt\%)} = (\text{weight of reactor after reaction}) - (\text{weight of empty reactor})/(\text{weight of feed}) \times 100$$

$$\text{Yield of gas(wt\%)} = 100\% - (\text{Yield of bio-oil (wt\%)} + \text{Yield of bio-char(wt\%)})$$

$$\text{Conversion(\%)} = 100\% - (\text{Yield of bio-char(wt\%)})$$

### 2.3 Pyrolysis experimental process:

Pyrolysis process consists of both simultaneous and successive reactions when carbon-rich organic material is heated in a non-reactive atmosphere. The thermal degradation of organic materials carried in the absence of oxygen. Thermal decomposition of organic components in the waste stream starts at 350°C–550°C and goes up to 700°C–800°C in the absence of air/oxygen. Pyrolysis of municipal waste were performed in a indigenously designed fixed bed reactor under atmospheric pressure using LPG at reaction temperature of 650 °C. Once the reaction time is over, the reactor is cooled and then bio-oil and biochar collected from the system. The gas samples were collected in the Tedlar bags and analyzed by GC. In this pyrolysis technique, the biomass has been converted into bio-oil, biochar, and gas products.

## RESULTS AND DISCUSSION

Proximate and ultimate analysis of the materials used in the present studies were presented in Table:1. The data is in agreement with the values reported in the literature for waste materials indicating a typical characteristic. The feed materials yielded an average of carbon of 48% and 56%, Hydrogen of 6% and 6%, Nitrogen of 0.4% &2%, Sulphur of 0.3% & 0.5% and oxygen of 45% & 34% respectively for paper and garden waste. Ash content and volatile matter were observed to be more in paper waste, where as moisture content and fixed carbon was found to be more in garden waste.

**Table.1: Analysis of the MSW for pyrolysis**

| Proximate analysis (Wt per cent) | Paper waste | Garden waste |
|---|---|---|
| Moisture | 6.7 ± 0.5 | 15.3 ± 0.5 |
| Ash | 13 ± 1 | 11 ± 1 |
| Volatile matter | 71 ± 1 | 61 ± 1 |
| Fixed carbon | 8 ± 0.5 | 11 ± 0.5 |
| **Ultimate analysis (Wt per cent)** | | |
| Carbon | 48 ± 1 | 56 ± 1 |
| Hydrogen | 6 ± 1 | 6 ± 1 |
| Nitrogen | 0.4 ± 0.05 | 2 ± 0.05 |
| Sulphur | 0.3 ± 0.05 | 0.5 ± 0.05 |
| Oxygen | 45 ± 1 | 34 ± 1 |
| Calorific value (K Cal/kg) | 4400 ± 20 | 5100 ± 20 |

In fact the yields as dependent upon the size of the feed, rate of heating, pressure and temperature of pyrolysis.

**Table.2: Analysis of the pyrolysis products**

| Product yields (Wt per cent) | At 600°C | | At 700°C | |
|---|---|---|---|---|
| | Paper | Garden waste | Paper | Garden waste |
| Char | 33± 1 | 37± 1 | 34± 1 | 30 ± 1 |
| Tar | 19± 1 | 20± 1 | 14 ± 1 | 15 ± 1 |
| Liquor | 29± 1 | 20± 1 | 28 ± 1 | 28 ± 1 |
| Gas | 12± 1 | 14± 1 | 14 ± 1 | 16 ± 1 |
| Calorific value of gas (K Cal/Nm3) | 2050± 20 | 2050± 20 | 1900 ± 20 | 2100 ± 20 |
| Calorific value of char (K Cal/kg) | 4200± 20 | 4450± 20 | 4356± 20 | 4656± 20 |
| $CO_2$ | 45± 1 | 49± 1 | 46± 1 | 52± 1 |
| CO | 28± 1 | 15± 1 | 27± 1 | 16± 1 |
| Hydrogen | 8± 1 | 9± 1 | 8± 1 | 10± 1 |
| Methane | 8± 1 | 14± 1 | 9± 1 | 13± 1 |
| Others | 10± 1 | 12± 1 | 9± 1 | 8± 1 |

### 3.1 Pyrolytic gas

In general, it is possible to say that composition of pyrolytic gas is strongly dependent on the pyrolysis temperature and feedstock. Pyrolysis of biomass waste and paper waste produces smaller amounts of gas, which is high in $CO_2$, CO and light hydrocarbons. The yields of gas in this conditions usually do not exceed 20 wt. % of products. Increasing the temperature causes increasing of gas yields, because of the second reactions and partial char decomposition. The most suitable desire of pyrogas is use them as a source of energy necessary for the pyrolysis. Combustion of this gas could provide the reactor heating. Therefore, emission control units and cleaning gas devices should be used and it does not matter whether gas will be combusted or not. The heating value to the gas observed to be 2050 K Cal/Nm3 (Table.2) for both type of smaples..

### 3.2 Pyrolytic Liquor

Depending on the composition of the feedstock and the process parameters composition of liquid phase from pyrolysis may be radically different. Pyrolytic liquor originated from biomass consist largely of the following compounds: acids, sugars, alcohols, ketones, aldehydes, phenols and their derivatives, furans and other mixed oxygenates (Dina et all, 2017). They can be used in order to production of heat, electricity, synthesis gas or chemicals. In general, co-pyrolysis of biomass and synthetic polymers could be an environmentally friendly way for the transformation biomass waste into valuable fuels. Moreover, co-pyrolysis allows simplifying expensive and complicated waste separation and classification process and still providing products.

### 3.3 Pyrolytic char

Pyrolysis conditions are usually optimized in order to maximize the liquid and gas products; however a solid fraction named as pyrolytic char also were produced. This char is mainly composed by a carbon-rich matrix that contains almost all the inorganic compounds present in the raw wastes and a significant amount of condensed by-products formed during the pyrolysis process dispersed throughout the solid porous structure (Chen D et al, 2014). The heating value of char obtained from pyrolysis of waste (mixture of biodegradable and non–biodegradable) was approximately 4200 to 4650 K Cal/kg, which is comparable with typical coal. However, as it is expected that some heavy metals and other hazardous elements, like S, Cl and N may also be retained in the solid products. Therefore, it is important to fully characterize char to assess their impact on the environment and humans. In general, this product can be combusted in order to provide energy for pyrolysis process or other purposes.

## CONCLUSIONS

1. The constant increase in the amount of waste produced by society makes the urgent need to develop new and better methods of disposal.
2. The municipal solid waste and similar materials can be pyrolysed to yield gas and tar of moderate heating.
3. The byproducts of pyrolysis could be used for pollutants removal from waste and air by adsorption process.
4. The pyrolysed products calorific values are good enough than the raw materials.
5. This could be adopted by urban local bodies in pilot scale for sustainable future.

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