

CHARACTERISTICS OF ORGANIC SOLID WASTE FOR LIQUID OIL PRODUCTION

M. N. Islam*, M. R. A. Beg and Dr.M. N. Islam

Department of Mechanical Engineering
Bangladesh Institute of Technology (BIT) Rajshahi, Rajshahi-6204, Bangladesh.

Abstract Organic solid waste are globally available throughout the world. Their utilization in a better way such as by thermochemical pyrolysis conversion method is considered for liquid oil production. For this purpose the organic solid wastes, i.e., plastic and rubber are characterized physically as well as for thermal behavior by TGA study. The physical characteristics of these wastes such as particle size distribution and bulk density have been considered. The elemental composition by ultimate analysis, in terms of carbon, hydrogen, nitrogen, and sulfur (CHNS) content of the selected wastes have been determined. From these studies it is found that plastic and rubber are suitable feed materials for pyrolysis conversion.

Keywords: Solid waste, Pyrolysis, TGA, Liquid oil.

INTRODUCTION

Apart from biomass solid waste, plastic wastes and scarp tire are of great importance. Plastic is a common material in every day life and because of its low density, it is more apparent as waste than might be indicated by statistics of nationwide and worldwide production. Thus, plastic and rubber represent a serious waste disposal problem. Selection and characterisation of feedstock are important in order for pyrolysis process to be successful. The waste which contains low moisture and low ash is suitable feed material for pyrolysis while the main economic criteria are cost and quantity that include availability. Plastic are among the best fruits of chemical industry and are used extensively in our lives. It is estimated that the annual world consumption of plastics in 1989 is about 50 million metric tons [Kuwahara *et al.*,1993] and the plastic markets are growing at the rate of 6-8% per year [Hashimoto, *et al.*,1994]. The amount of waste plastic generated is alarming. It was estimated that the public discarded 22 lbs of waste plastics out of 55 lbs of plastics the industry produced in 1988 [Szepe and Levenspiel,1994]. In Bangladesh the accumulation of scrap-tire from transport vehicle and refused plastic materials are increasing day by day. The total number of transport vehicle in Bangladesh is about 6,01,639 [Statistical Yearbook 1999]. A large quantities of these waste are produced from these vehicles. In many cases the waste is free and may even have a credit or negative cost for disposal. For these reasons, organic solid wastes are considered attractive feedstock for conversion, since the cost are low or even negative, i.e. to attract a disposal

credit so that disposal problem can be mitigated. Roughly 75 percent of the discarded tires are disposed of in landfills; 20 percent are retreaded; and 5 percent are reclaimed, burned for fuel, split, etc [Schuiman and White, 1976]. Probably the best alternative for rubber pyrolysis to yield liquid oil on large scale would be possible, although the fuel cost increments for natural and coal are lower than scrap rubber. As fuel cost escalate, there will be more incentive to use scrap tires for oil production. Mostly the waste plastic and scrap tires are either unutilized or under utilized as a source of heat energy. Some of these was used as fuel by direct burning. Burning these wastes in a uncontrolled manner causes a serious emission problem. Thus there is scope to utilize these waste in better way which would contribute to mitigate environmental problem.

CHARACTERISATION STUDIES

The study of characteristics of organic solid waste are important for pyrolysis conversion. High volatile matter content is desirable for liquid oil production [Bridge water and Bridge, 1991] with low moisture and ash. The physical properties, such as bulk density, particle size, proximate and ultimate analysis, heating value and thermal behavior characterization by TGA study have been considered here.

Physical Properties

Bulk density and particle size are the important physical characteristics of the solid waste for thermochemical conversion [Rossi, 1984]. Bulk density depends upon the moisture content, shape and size of the feed material.

* Email: bitrme@rajbd.com

It also depends on the preparation method, like milling, shaping etc. The bulk density of the wastes is shown in Table-1. The particle size and products from pyrolysis are interrelated arising kinetic considerations and rates of heat transfer. Usually the proportion of different product phases are affected by particle size : the smaller the particle size, the quicker the reaction and hence the greater the yield of organic products in liquid form.

Proximate and Ultimate Analysis

Proximate analysis is a simple test of the quality of a sample. It gives in percentage the amount of moisture, volatile matter, fixed carbon and ash content. The result of the proximate analysis are shown in Table-2. Ultimate analysis gives the amount of carbon, hydrogen, oxygen, nitrogen and sulfur (CHNOS).in a sample in terms of percentage by weight, were important in pyrolysis conversion. These analyses were conducted according to the ASTM test procedures in the Laboratory of Fuel Research and Development Institute, Bangladesh Council of Science and Industrial Research, Dhaka, Bangladesh. The ultimate analysis of organic solid waste is given in Table- 3.

Table-1: Bulk density in kg/m³ and wt% of respective particle of their total weight of the organic solid wastes

Organic solid wastes	0 to 300µm	300 to 600µm	600 to 1180µm	300 to 1180µm
Plastic	260.00 (4.0%)	286.00 (24.0%)	299.00 (72.0%)	292.50 (96.0%)
Rubber	240.54 (15.6%)	268.75 (48.8%)	250.00 (36.36%)	259.375 (84.84%)

Table-2: Proximate analysis of the solid wastes

Organic solid wastes	Moisture content %wt	Ash content %wt	Volatile matter %wt	Fixed carbon %wt
Plastic	0.41	2.43	96.88	0.28
Rubber	0.82	4.17	62.70	32.31

Table-3: Ultimate analysis of the solid wastes (ash free, by difference)

Samples	C wt%	H wt%	N wt%	O wt%	S wt%
Plastic	83.93	12.84	-	0.80	-
Rubber	80.30	5.18	-	10.33	-

Higher heating value

The higher heating value of the prepared samples were determined using Plain Oxygen Bomb Calorimeter.

Approximately 1gm of the sample was placed in a crucible inside the calorimeter. The bomb was filled with oxygen under a pressure of 30 atm . The sample was then ignited by passing a low voltage current through the firing circuit. The rise in the temperature of water was a measure of heat released by combustion. The gross calorific value of the selected solid wastes for particle size of 300 to 1180µm are given in Table – 4.

Table-4: Higher heating value of organic solid waste

Organic solid waste	Heating Value kJ/kg
Plastic	37001.00
Rubber	33301.20

Thermal Gravimetric Analysis (TGA)

Thermogravimetric (TG) plot determination: The thermal characteristics of waste plastic and rubber particles have been investigated by thermogravimetric analyzer (TGA) study. The instrument used for this purpose was SHIMADZU TGA-50 model and the tests were conducted at the laboratory of Fuel Research and Development Institute, BCSIR, Dhaka, Bangladesh. The samples for investigation were air dried and were of sizes of 300 to 1180 µm. Each of samples was subjected to different controlled heating rates over a temperature range of 0°C to 1000°C. The heating rates employed were 10° and 20°C/min for both plastic and rubber. During the process of pyrolysis, the weight percentages of the initial weight of the sample were recorded continuously as function of temperature and time by a computer connected to the system and from these recordings, thermogravimetric (TG) plot was obtained. The TG curve indicates the fractional weight loss of the sample with temperature and time. The plots obtained at two heating rates of 10° and 20°C/min for these waste are presented in Figs. 1,2,3,4.

Plastic-20

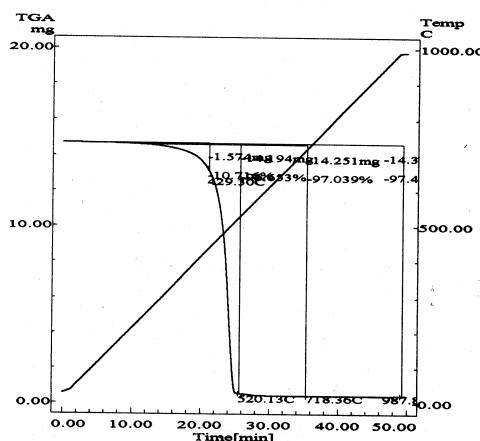


Fig. 2 TG plot for plastic in helium at 20°C/min.

Plastic-10

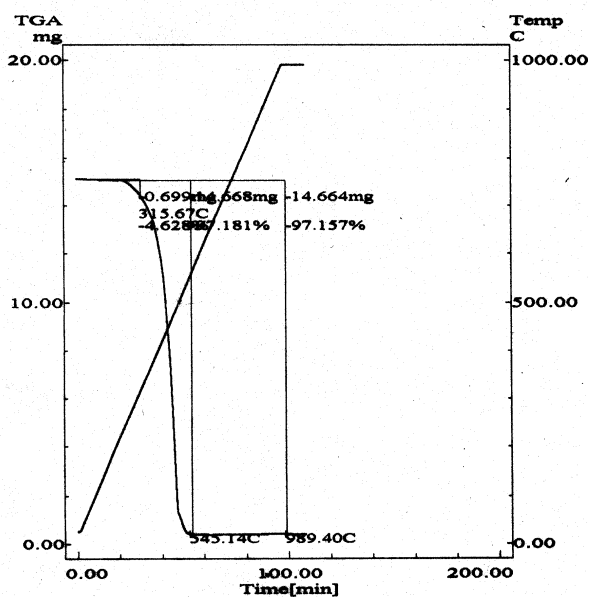


Fig. 2 TG plot for plastic in helium at 10⁰ C/min.

RUBBER-10

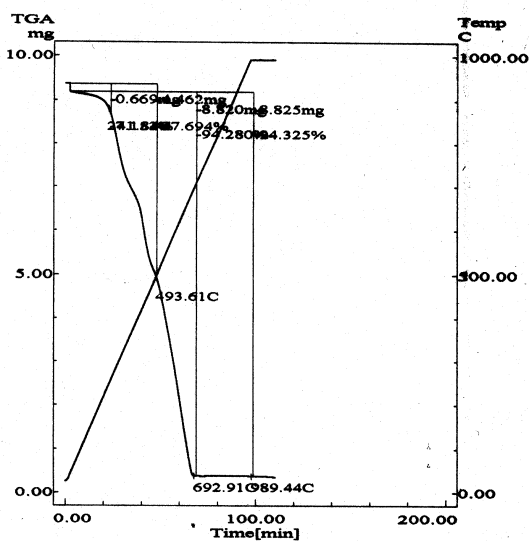


Fig. 4 TG plot for rubber in helium at 10⁰ C/min.

RUBBER-20

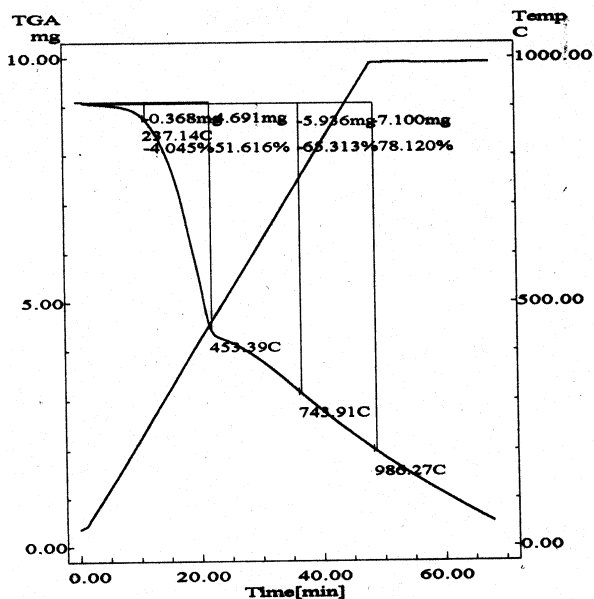


Fig. 3 TG plot for rubber in helium at 20 C/min.

Determination of degree of conversion: By using the values obtained from TG plots, the degree of conversion of the selected solid waste, X, in pyrolysis reaction can be derived as defined by Equation (1) [Liou and Chang, 1997]

$$X = (W_o - W)/(W_o - W_\alpha) \dots \dots \dots (1)$$

Where W_o = initial mass, W = instantaneous mass and W_α = final mass of the sample.

Figs. 5 and 6 presents the plots of degree of conversion against temperature of plastic and rubber at heating rates of 10 and 20°C/min respectively.

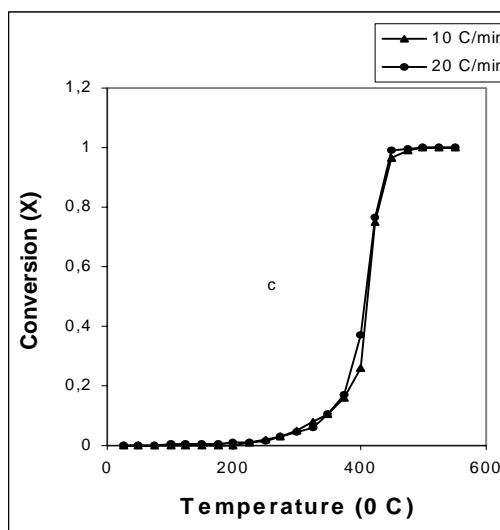


Fig. 5 Effect of heating rates on the pyrolysis conversion of plastic.

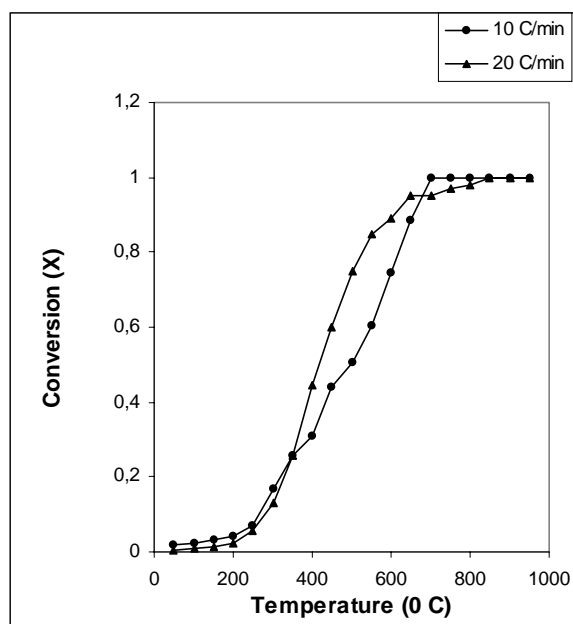


Fig. 6 Effect of heating rates on the pyrolysis conversion of rubber.

From Table-1 it is found that more than 95% weight of the particles of each of prepared samples were in the size range of 300 to 1180 μ m and the bulk density of the particles within this range were higher than that of particle size range of 0 to 300 μ m. The preparation of larger particle is easier and less energy consuming. The higher density particle takes less volume in the reactor of the pyrolysis conversion system. This criterion of the feed material makes the system less energy consuming for their pyrolysis conversion.

Table-2 shows that there are high percentage of volatile matter and low ash content for both samples, which prove that these wastes are suitable for liquid oil production. Also Table-3 shows that these waste contains small amount of oxygen by weight percent which favors them for pyrolysis conversion.

In the conversion plots, shown in Figs. 5 and 6, there are clearly three principal stages of reaction. Three significant and distinct variation of conversion for each of two heating rates for all of the samples. For a given temperature of the sample pyrolysis, the corresponding conversion at a higher rate of heating was more than that at a smaller rate of heating. However the variation is not significant the degree of conversion of each solid wastes were found to increased by less than 5% when temperatures were varied up to 275 $^{\circ}$ C for both heating rates. This may be related partly to the devolatilisation and hemicellulose contained in the wastes. The second stage with a degree of conversion of up to 95% in case of plastic when the temperature was varied from 280 to 450 $^{\circ}$ C is mainly attributed to the decomposition of the organic constituents into volatiles and char [Islam and Nasir,1999]. The third stage indicating conversion after

95% involve the gradual breakdown of the lignin into char and gases when the temperature was varied from 425 to 500 $^{\circ}$ C for plastic. When the temperature exceeded 450 $^{\circ}$ C the organic materials were completely decomposed. In case of rubber, this temperature was varied from 600 to 650 $^{\circ}$ C and When the temperature exceeded 650 $^{\circ}$ C, the organic materials were almost completely decomposed to carbon and other inorganic compounds and higher pyrolysis temperature did not affect the loss of mass.

CONCLUSION

From the characterisation studies it is apparent that the waste plastic and the scrap rubber have high volatile content which are suitable for pyrolysis conversion into liquid product. The degree of conversion and rate of devolatilisation were found to be maximum in the pyrolysis temperature range of 375 to 450 $^{\circ}$ C and 300 to 600 $^{\circ}$ C for plastic and rubber respectively. In case of plastic the devolatilisation was taking place completely and ended at 450 $^{\circ}$ C while for rubber this temperature was a bit higher than about 600 $^{\circ}$ C. Thus the reactor should be designed for each of these organic solid waste with temperature range of 300 to 600 $^{\circ}$ C. The heating system is to be designed to heat the feed material at a rate of 10 $^{\circ}$ C/min.

ACKNOWLEDGEMENT

The authors wish to thank the Ministry of Science and Technology of the Governments of Peoples Republic of Bangladesh for providing the financial support and Bangladesh Institute of Technology (BIT), Rajshahi, Bangladesh and Bangladesh Council of Science and Industrial Research (BCSIR), Dhaka, Bangladesh for their laboratory facilities to carry out the experimental studies of this research work.

REFERENCES

- Kuwahara, H., Songip, A. R., Masuda, T., and Hashimoto, K., "Effects of Steam Co-feeding in the Catalytic Cracking of Heavy Oil from Waste Plastics over Nickel Supported REY Zeolite", *Energy & Fuels*, 8 (1), 136-140 (1994).
- Hashimoto, K., Masuda, T., Songip, A. R., and Kuwahara, H., "Production of Gasoline from Oil Obtained from Pyrolysis of waste Plastics Under Steam Atmosphere", submitted for Japanese Patent, In Japanese, 1994.
- Szepe, S. And Levenspiel, O., Proc. 4th Eur. Symp. Chem. Reaction Eng., Brussels, Pergamon Press, London, 1971.

- B. L. Schulman and P. A. White, "Pyrolysis of Scrap Tires Using the Tosco II Process", – progress Report, rept. ACS Symp. Ser. 76 (1976).
- Bridgwater, A.V. & Bridge, S.A. "A Review of Biomass Pyrolysis and Pyrolysis Technology", In: Bridgwater, A. V. & Grassi, G. (Eds.). *Biomass Pyrolysis Liquid Upgrading and Utilization*. London: Elsevier Applied Science; 11-92 (1991).
- Islam, M.N. and Nasir, F. "Thermal Characteristic of Malaysian Rice Husk". *J. Tech.*, 30, 39-50 (1999).
- Rossi, A. "Fuel Characteristics of wood and non-wood biomass fuels". In D.A. Tillman and E.C. Jahn. (Eds). *progress in Biomass Conversion*. New York: Academic Press. pp 69-96.
- Liou, T-H., F. W. Chang and J. J. Lo. "Pyrolysis Kinetics of acid leached rice husk". *Ind. Eng. Chem. Res.*, 36 568-573 (1997).