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Comparative Thermal Decomposition Studies of Newspaper, Cardboard and Glossy paper

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ABSTRACT

The side effect of growth in gross domestic products (GDP) is the fast generation of municipal solid waste which leads to challenges in the handling and disposal of MSW. Almost 4–6 percent of the existence of various papers, such as printing paper, glossy paper, newspaper, or cardboard, exists in MSW. Normally, all papers are recyclable, but because all papers are collected from the dump site after disposal, recycling of such papers is difficult. To overcome this issue, conversion of such waste papers into energy using either pyrolysis, gasification, or incineration technology is required, and knowledge of reaction kinetics is required to design the reactors for such waste technology. The objective of the present work is to carry out comparative thermal decomposition studies of newspaper, cardboard, and glossy paper (all papers) at heating rate of 10 ºC/min with their residue analysis also using a scanning electron microscope.

KEYWORD: Municipal Solid Waste (MSW), Reaction Kinetics, Scanning Electron Microscope (SEM).

1. INTRODUCTION

Waste, particularly MSW, which consists of papers, plastics, composted waste, and non-combustible items, is a heterogeneous mixture of the aforementioned constituents, and converting MSW into energy requires energy. The depletion of fossil fuels, greenhouse gas emissions, and handling solid waste are challenges faced by the present world. Normally, waste is treated as an unproductive substance, but the interesting part is that, energy is consumed during manufacturing, as "raw material is converted to waste." This implies that waste is a source of energy. Waste has devastating effects on the economy of a country and the health of society, directly or indirectly. Waste handling methods in developing countries are very crude, like land filling; but with the proper utilisation of technology using thermal conversion options like incineration, gasification, and pyrolysis, a large quantity of waste can be converted into a sizeable amount of energy. It is evident that each technology has its own advantages and limitations.

The present work begins with waste-to-energy options and concludes with a proposed technology called vacuum pyrolysis for extracting energy from waste. The ever-increasing amount of MSW produced in the modern world has resulted in a slew of societal and health issues. Waste-to-energy is the right alternative for meeting energy demand while also finding a proper MSW solution from an economic, social, and environmental standpoint. With high GDP rises all over the world, the MSW generation also increases. The per capita MSW generation in developed countries varies from 0.5 to 2.0 kg, while for underdeveloped countries this figure lies on average in the range of 0.4 to 0.8 kg.

Ruth L.A (1998) [1] compared coal and municipal solid waste burning in terms of fuel parameters, combust mode, emissions, and ash usage/disposal. Coal and MSW co-combustion is also investigated. There are a number of MSW challenges that can be solved by research and innovation. **Saxena S.C (1993) [2]** discussed the status and progress of fluidized-bed technology in terms of environmentally acceptable waste disposal for various types of trash's. Fluidized-bed incinerators have a number of advantages over conventional incinerators, including compact furnaces, simple designs, impactful burns of a wide range of fuels, relatively consistent temperature, ability to lower NO_2 and SO_2 gas emissions, high pyrolysis rate of trash products, and high rates of solid particle oxidation.

From a technical, economic, and environmental standpoint, **J.D. Murphy and E. McKeogh (2004) [3]** describe the four available technologies for MSW–to–Energy, namely, incineration, gasification, production of synergy gas, and usage in a combined heat and power (CHP) plant for the creation of synergy gas and converting to transportation fuel. From proximate study of biomass materials, **Jigisha Parikh, S.A. Channiwala, and G.K. Ghosal (2004) [4]** derived the correlation to predict the elemental analysis of biomass materials. The goal of developing this formulation is to deal with the challenges of ultimate analysis and rapid elemental composition calculation. **A.N. Garcia, A. Marcilla, and R. Font (1995) [5]** reported the kinetics of MSW pyrolysis at varied heating rates between 1.5 and 200 °C/min. The effect of heating rate and heat transfers on the kinetic variables that may be estimated from the statistics was investigated. This was done as a result of our results and what we learned.

Chao-Hsiung Wu, Ching-Yuan Chang, Jyh-Ping Lin, and Jiann-Yuan Hwang (1997) [6] provided a kinetic research of coated printing and writing paper spanning the temperature ranging 450-900 K with two phases of degradation using thermogravimetric analysis in nitrogen. **L. Sorum, M.G. Gronli, and J.E. Hustad (2001) [7]** focused on providing comprehensive data on the pyrolysis variables and chemical dynamics of most crucial MSW materials. In an inert atmosphere, TGA with kinetic parameter evaluation is performed at a heating rate of 10 ^{o}C/min. To simulate the cellulosic portion of MSW, three separate parallel processes reflecting the breakdown of hemicellulose, cellulose, and lignin were used.

C. David et al. (2003) [8] investigated the pyrolysis process based on a series of TGA measurements for cardboard. The study involves the determination of kinetics variables for cardboard. This study also uses a series of TGA tests to investigate the pyrolysis phenomena and compare the graphical method's outcomes to numerical results that are in good agreement. **J.M. Encinar and J.F. González (2008) [9]** studied the kinetics of PS, recycled plastics, LDPE, ABS, polyenterophthalate of ethylene, and PP under N_2 atmospheres at heating rates of 5–30 K min^{-1}.

In a pilot scale reactor in a N_2 atmosphere, **N. Miskolczi, A. Angyal, L. Bartha, and I. Valkai (2009) [10]** studied the pyrolysis of plastics trash from the agriculture as well as packaging industries using a ZSM-5 catalyst up to 520 ^{o}C. The catalyst used facilitated in the production of i-butane in gases but had an impact on gasoline and light oil composition. Significant quantities of P, Ca, N, and S could be present in all products in this condition, although the catalyst has lowered impurity levels.

2. EXPERIMENTATION - THERMOGRAVIMETRIC ANALYSIS (TGA)

In the SEIKO TG/DTA-32 thermal system, thermogravimetric and differential thermogravimetric analyses were performed. Samples were scanned between room temperatures to 600 ^{o}C at a heating rate of (β) 10 ^{o}C/min in a N_2 environment and a flow rate of 50 ml/min. The volume of sample which can be used is limited to 6 mg. Samples used were kept in a crucible made of platinum and α alumina was utilised as a reference.

3. RESULT AND DISCUSSION

(A) Thermal Decomposition Behavior of all papers

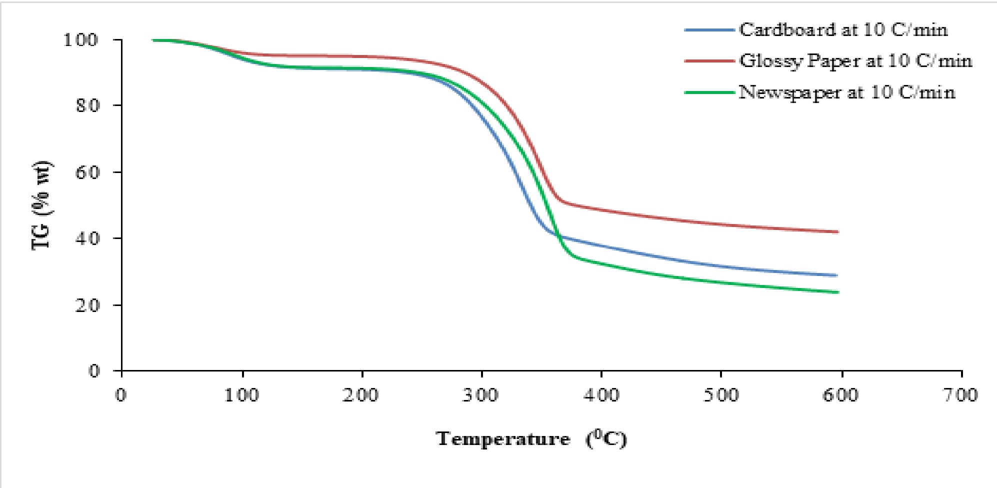


Fig. 1 Thermogravimetric Analysis of all papers

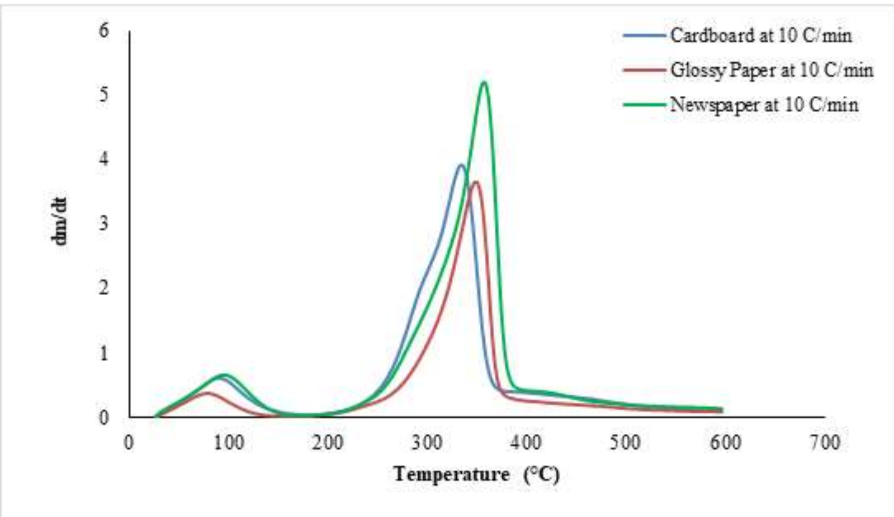


Fig. 2 Differential Thermogravimetric Analysis of all papers

Figures 1 and 2 indicate the thermal decomposition of all papers, and it is clearly observed that decomposition occurs in three phases and maximum decomposition occurs in newspaper and a minimum in the case of glossy paper due to the presence of more clay in the glossy paper, making the peak of glossy paper lower compared to the peak of newspaper, while the peak of cardboard lies between newspaper and glossy paper. The peak temperature of a newspaper is 353.7 °C and that of glossy paper is 341.1 °C. From fig. 2, it can be seen that there is a lateral shift of the peak. This may be because the high decomposition rate leads to the release of more energy which enhances the temperature value. In the case of all the papers, the three peaks are frequently observed and the temperature range wherein the highest peak may be noticed which varies from 175-250 °C, 300-425 °C and 450-525 °C, which correspond to hemicellulose, cellulose, and lignin, respectively [7, 8].

Table 1: For all papers, % of losing weight in phases of decomposition corresponds to temperature range

Heating Rate (⁰C/min)	First Stage		Second Stage		Third Stage		% Residual remains
	% Weight Loss	Temp Range ⁰C	% Weight Loss	Temp Range ⁰C	% Weight Loss	Temp Range ⁰C	
Newspaper							
10	5.6	30-233.6	57.1	233.6-361.1	26.1	361.1-538	11.2
Glossy Paper							
10	7	30-255.1	33	255.1-346.3	18	346.3-534.2	42
Cardboard							
10	6	30-193.3	53	193.3-366.5	24	366.5-539.6	17

Table 1 represents the decomposition of different paper wastes and their corresponding temperatures. It is observed that maximal degradation takes place in the context of newspapers and a minimal in the case of glossy papers. The residual values are highest in the case of glossy paper waste, which is about 40% in the case of all heating rates. The decomposition rate in the case of glossy paper is quite slow, which may be due to the presence of clay in the case of glossy paper. The decomposition occurs in the second stage, which is in the range of 30–70%. In the case of the first stage, the decomposition is quite slow and is in the range of 6–12%, and the corresponding temperature range varies from 25–275 °C. In the case of glossy paper, the first stage of decomposition is slow compared to any other paper.

(B) Elemental Analysis of all papers

The elemental analysis of residue of all papers which is generated at heating rate of 10 °C/min is shown below in figures 3 to 8. Table 2 indicates that due to more thermal decomposition, more carbon exists in newspaper and less in glossy paper, but more calcium exists in glossy paper due to more clay being used in the case of glossy paper.

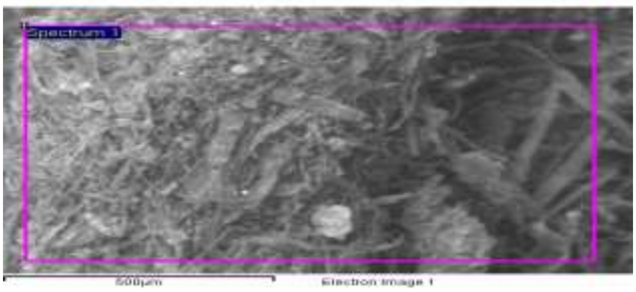


Fig. 3 Cardboard Residues (10 ⁰C/min)

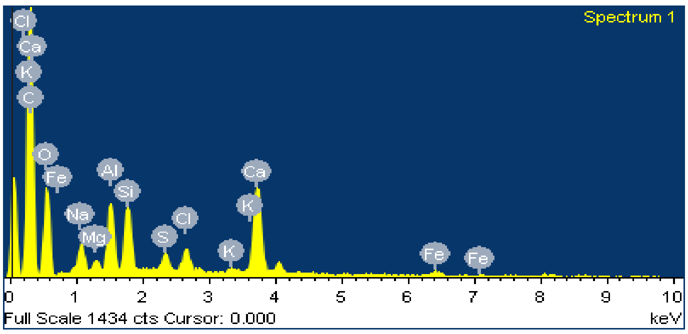
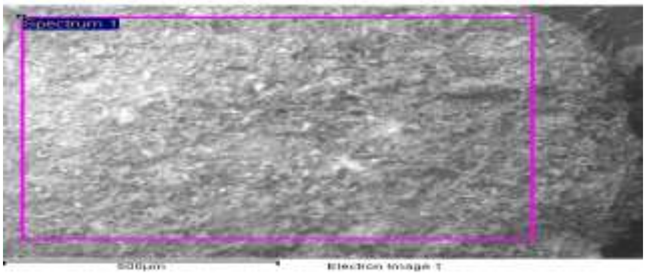


Fig. 4 Elemental Spectrum



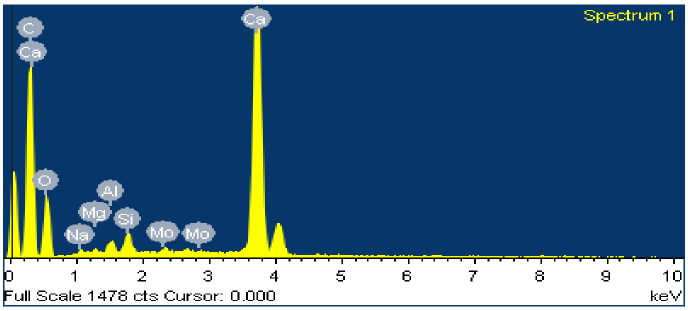
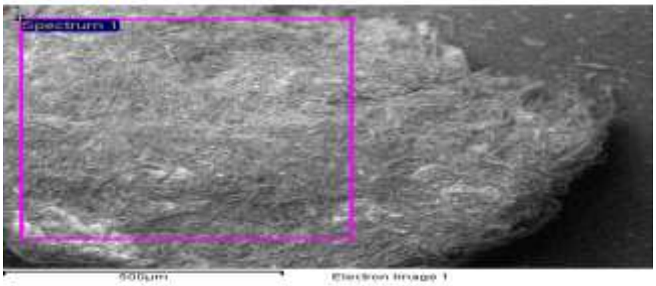


Fig. 5 Glossy Paper Residues (10 ^{0}C/min) **Fig. 6 Elemental Spectrum**



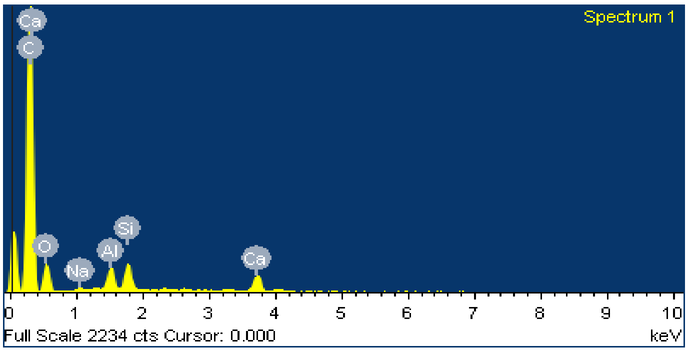


Fig. 7 Newspaper Residues (10 ^{0}C/min) **Fig. 8 Elemental Spectrum**

Table 2: Elements present in all papers

Cardboard														
Heating Rate	**Element**	**C**	**O**	**Na**	**Mg**	**Al**	**Si**	**S**	**K**	**Mo**	**Fe**	**Ca**	**Cl**	**Total**
10 ^{0}C/min	**Weight %**	58.65	28.32	1.43	0.48	2.23	2.24	0.62	0.16	0	0.52	4.45	0.91	100
Glossy Paper														
10 ^{0}C/min	**Weight %**	44.03	33.54	0.31	0.28	0.66	0.96	0	0	0.70	0	19.52	0	100
Newspaper														
10 ^{0}C/min	**Weight %**	73.85	21.11	0.24	0	1.38	1.65	0	0	0	0	1.77	0	100

4. CONCLUSION

The major conclusion of the present research work is that the thermal decomposition of newspaper occurs at a faster rate than glossy paper at the same heating rate, and due to better thermal decomposition, there are fewer residues of 11.2% in newspaper.

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