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Thermal Degradation of Solid Biomass Wastes

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Solid waste management has become a global problem. These wastes are generated from various sectors. Some of these are segregated for recycle and recovery and biological wastes are used for vermicomposting. All other wastes need to be destroyed. The best method for destruction is through thermal degradation (incineration). For such purposes laboratory studies were conducted on thermal decomposition of biomass wastes, which have been reported in the present communication. A brief survey of solid waste status in Delhi city is also described here.

Key Words: Solid biomass waste, Incineration, Thermal treatment, Residue analysis.

INTRODUCTION

With the influx of industrial revolution coupled with ever-escalating urbanization, increasing consumerism and population exodus, the problem of solid wastes has inflated significantly[1]. Waste production has been a part of human activity since time immemorial. Now it is realized that the waste accumulation may seriously affect the stability of the atmosphere[2].

Previously, solid wastes were considered any solid matter, which were not useful for any practical purpose and ultimately discarded. For more than a decade, this definition has changed.

As given by RCRA (Resource Conservation and Recovery Act) of 1976, regulation 6903 (27)[3], a solid waste is defined by the act as the following. Any garbage, sludge, refuse from a waste treatment plant, water supply treatment plant or air pollution control facility and other discarded material including solid, liquid, semisolid or contained gaseous material resulting from industrial, commercial, mining and agricultural operations and from community activities. The regulatory definition[3] is given in 40 CFR 261.3(a) (1). By regulations it is defined as "Any discarded material not expressly excluded by the definition". The disposers of solid waste (which is not hazardous) must meet the criterion.

Improper handling of solid wastes can be a source of land, water and air pollution. Poor solid waste management is associated with adverse impacts on all components of environment and human health. Leachate from dumping grounds contaminates the ground water and sub-soil that leads to health hazards. Open burning of street waste and escape of landfill gas increases air pollution load of the city and contributes significantly to global warming. Poor collection and disposal of solid waste can tigger off epidemics[4].

Solid wastes differ from air and water pollutants since they are heterogeneous in nature. The composition and rate vary from day to day, from season to season and from locality to locality. The terminologies used with respect to solid wastes have been standardized by the Institute of Solid Waste of American Public Works Associations and the office of Solid Waste Management of Environmental Protection Agency[5]. The terminologies used are Refuse, Trash, Garbage, Rubbish, Litter and Industrial Waste. Solid wastes can be inorganic type (fly ash, mine tailings, polish tailings etc.) or municipal wastes containing domestic biomass wastes[6].

A survey was conducted on the characterization of the solid wastes generated in Delhi, India[7]. The National Capital Territory of Delhi (NCT) is covered by three local bodies, which are responsible for civic administration[8]. They are Municipal Corporation of Delhi (MCD), New Delhi Municipal Corporation (NDMC) and the Delhi Cantonment Board (DCB). The MCD is the largest among the three in terms of both area and population, occupying 94.22% (1,397.29 sq. km.) of total area of 1,483 sq. km. and 95.80% of the population of Delhi[9]. The MCD administration has divided the whole area of Delhi into a total of 12 zones. Each of the zones can be considered as a separate Municipal Corporation by the standard followed by the other states (Table-1).

TABLE-1
MCD ZONES AT A GLANCE

Zones	No. of wards	Population in 1996	Percentage
City	8	5,40,896	4.71
Central	12	8,11,995	7.07
South	12	13,48,961	11.74
Karol Bagh	8	6,08,228	5029
Sadar Paharganj	6	5,21,841	4054
West	16	13,41,849	11.68
Civil Lines	10	8,22,206	7.16
Shadara (S)	16	12,99,410	11.31
Shadara (N)	16	13,77,503	11.99
Rohini	12	12,02,224	10.46
Narela	4	3,40,294	2.96
Najafgarh	14	12,67,806	11.04
MCD	134	1,14,83,213	100.00

A recent study has shown that organic content of the city refuse in India is much higher (Table-2) due to the practice of using agricultural products unlike consumption of tinned and prepared foodstuff in developed countries[10]. High organic fractions necessitate frequent disposal of waste.

TABLE-2
VARIOUS COMPONENTS OF CITY REFUSE

S. No.	Refuse	% (By weight)
1.	Food waste and foliage	50–60
2.	Paper and card	4–10
3.	Plastic, leather and rubber	1–2.2
4.	Glass	1–2
5.	Metals	1–3
6.	Fine earth and ash	20.5–25
7.	Bones	0.5–1
8.	Textile	1–2
9.	Stones etc.	5–7

In developed countries, more of paper waste is produced compared to developing countries (Table-3).

TABLE-III
COMPARATIVE PICTURE OF CITY REFUSE COMPOSITIONS
(STANDARD OF LIVING EFFECT)

Item	European	Composition, weight %	
		North American City	Indian City
Mixed paper	20–35	40–50	3–8
Wood and textile	4–7	2–6	—
Plastic and rubber	3–7	4–7	1–2
Putrescibles	20–23	20–25	33–42
Fines and ash	15–20	5–8	32–47
Metal	3–6	5–7	0.5–1.0
Glass	5–9	5–9	1
Heating value	1500–2300	2300–2800	800–1100

The quantity of waste from various cities was measured by NEERI (National Environmental Engineering Research Institute). The quantity of the waste produced is less than that in developed countries and is normally observed to vary between 0.2–0.6 kg/capita/day. Value up to 0.6 kg/capita/day is observed in metropolitan cities (Table-4). The total waste generation in the urban areas of the country is estimated to be around 38 million tonnes per annum[11].

TABLE-4
QUANTITY OF MUNICIPAL SOLID WASTE IN INDIAN URBAN CENTRES

Number of urban centres (Sampled)	Total population (In millions)	Average per capita value (kg/capita/day)	Quantity (tonnes/day)
328	68.300	0.21	14343
255	56.914	2.00	11952
31	21.729	0.25	5432
14	17.184	0.27	4640
6	20.597	0.35	7209
3	26.306	0.50 *	13153

*0.6 kg/capita/day generation of MSW observed in metro cities.

Waste composition also varies with social economic status within a particular community, since income determines life-style, consumption patterns and cultural behaviour. Table-5 shows the data for different degrees of national wealth (annual per-capita income) and the percentage of waste type generated[12, 13].

TABLE-5
PATTERNS OF COMPOSITION, CHARACTERISTICS AND QUANTITIES

	Composition (% by weight)		
	Low income 1	Middle income 2	High income 3
Metal	0.2–2.5	1–5	3–13
Glass, ceramics	0.5–3.5	1–10	4–10
Food and garden waste	40–65	20–60	20–50
Paper	1–10	15–40	15–40
Textiles	1–5	2–10	2–10
Plastic/rubber	1–5	2–6	2–10
Misc. combustible	1–8	—	—
Misc. incombustible	—	—	—
Inert	20–50	1–30	1–20
Density (kg/m^3)	250–500	170–330	100–170
Moisture content (%)	40–80	40–60	20–30
Waste generation (kg/cap/day)	0.4–0.6	0.5–0.9	0.7–1.8

1. Countries having a per capita income less than US$ 360 (1978 prices).
2. Countries having a per capita income US$ 360–3500 (1978 prices).
3. Countries having a per capita income greater than US$ 3500 (1978 prices).

It has also been shown that the middle and low-income countries have high amount of compostable matter/content in their municipal solid wastes. Ash is one of the main substances constituting the 'other' category, especially in India and China[13]. As the per capita income goes up, the volume of wastes generated are expected to go up[13]. Management and disposal of such wastes create a lot of problems. The disposal of these wastes can be done by incineration which is one of the efficient and acceptable methods[14].

Incineration is the process of destruction of wastes at high temperatures. It is essentially a combustion process. Like any other combustion process, it is carried out in a furnace type enclosure, with provisions for sufficient air to complete the process. The most critical factors that affect combustion are temperature in the combustion chamber, residence time, degree of turbulence and oxygen available[14]. An essential application of the combustion process, incineration has now become an integral part of the solution to toxic/hazardous waste management problems. For a municipal incinerator, the categories of the waste could be paper, plastics, leather, rubber, textiles, wood, food wastes, yard wastes and miscellaneous (inorganic, ash, dust etc.). Waste incinerators are being strongly advocated by the Environmental Protection Agency (EPA) as it is a technology of choice for many types of hazardous wastes. Incineration is particularly effective with organic wastes as solids, gases, liquids, slurries and sludges.

In developed nations domestic wastes are normally incinerated (using kitchen incinerators) and hence the problems of garbage accumulation and other associated problems are not observed. Domestic waste generated in India is very different comprising mainly of kitchen wastes, glass, metals, fabrics, plastics and some miscellaneous items. Biodegradable wastes are normally used for vermicomposting. However, glass, metals and plastics (at most places) are segregated for recycling. The rest needs to be destroyed (through incineration). Characteristics of such wastes need to be known for designing incinerators.

It has been attempted to conduct some laboratory scale experiments on domestic (kitchen waste) to have a precise idea of their characteristics when they are incinerated/thermally treated. These experimental studies have been detailed in the present paper.

EXPERIMENTAL

For studying the characteristics hot air oven, muffle furnace and a precision balance were used. Experiments were conducted using the conventional laboratory glasswares and silica crucibles. Wastes used were solid biomass type kitchen wastes, saw dust and corn cob, which were collected locally. Moisture content of the material plays an important role in combustion/incineration. Hence, proximate analysis of the samples was conducted. Wood, being a standard sample, was also studied under the same conditions.

Samples of biomass having extreme characteristics (high moisture content and relatively low moisture content) were chosen for the study, since their behaviour would mark the boundary conditions for combustion of other materials. The combustion characteristics of a mixed waste would be within these limits and predictably an average of these. In case of thermal degradation characterization of materials is very important. A standard sample of wood was chosen whose combustion characteristics are better understood, to serve as a basis for comparison. The moisture content, volatile matter, ash and fixed carbon of these samples were determined which are shown in Table-6.

TABLE-6
PROXIMATE ANALYSIS OF SAMPLES

S.No.	Sample	Moisture (%)	Volatile matter (%)	Ash content (%)	Fixed carbon (%)
1.	Tomato	61.73	24.75	13.34	2.82
2.	Brinjal	35.70	5.70	58.39	29.50
3.	Radish	84.74	4.66	9.56	1.04
4.	Carrot	91.66	4.38	3.94	0.02
5.	Beans	88.01	3.65	1.22	7.12
6.	Cauliflower	91.40	3.73	4.60	0.27
7.	Saw dust	80.76	1.69	0.24	17.31
8.	Corn cob	84.45	2.73	1.27	11.55
9.	Wood	11.63	67.12	0.84	20.41
10.	Capsicum	83.28	2.28	1.48	12.96
11.	Spinach	93.28	3.46	2.22	1.04
12.	Pumpkin	80.62	1.38	2.80	15.92

RESULTS AND DISCUSSION

Combustion behaviour of the different samples was studied. Variations in moisture content and volatile matter content of the samples have been shown in the bar chart (Figs. 1 and 2). Results of a few individual samples have been plotted to show the variation in weight loss with time as shown in Figs. 3, 4 and 5. The comparative weight loss with respect to time for different biomass samples have been depicted in Fig. 6. Samples having high moisture content lose most of their weight initially (in 2–5 min) and after combustion are reduced to approximately 5% of the initial weight with the exception of a few. Samples having high ash content loset weight steadily, until they achieve constant weight. Reduction in weight is about 50%. There was some residue left after combustion. The residue generated was further analyzed.

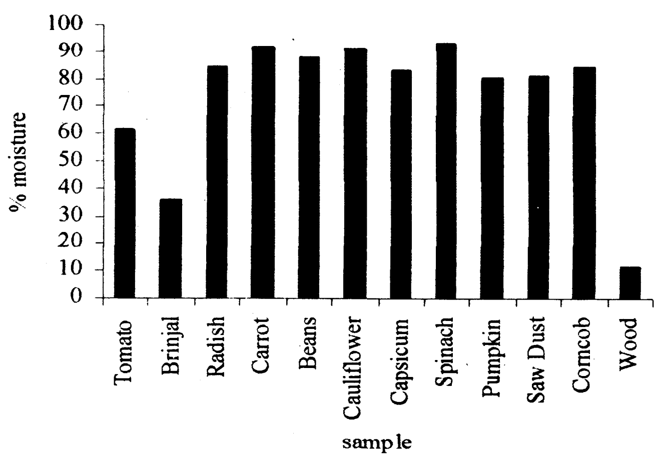

Fig. 1. Per cent Moisture of biomass samples

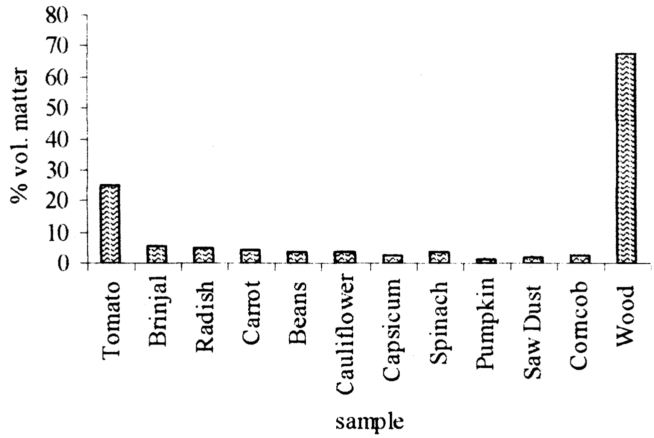

Fig. 2. Per cent volatile matter of biomass samples

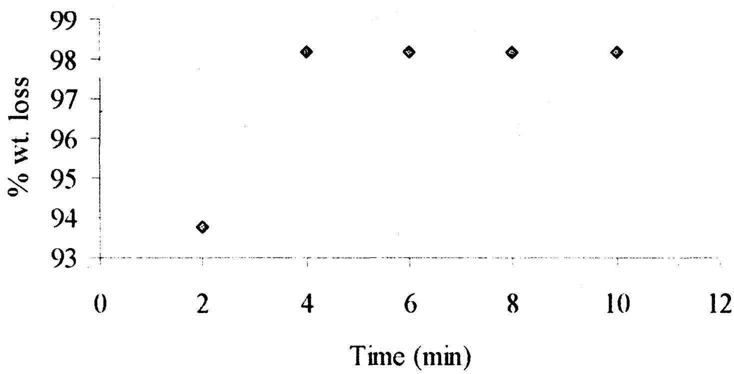

Fig. 3. Per cent weight loss with respect to (w.r.t.) time for Radish

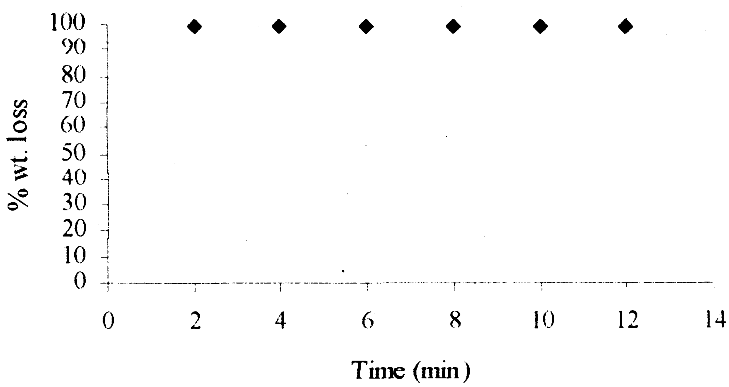

Fig. 4. Per cent weight loss w.r.t. time for carrot

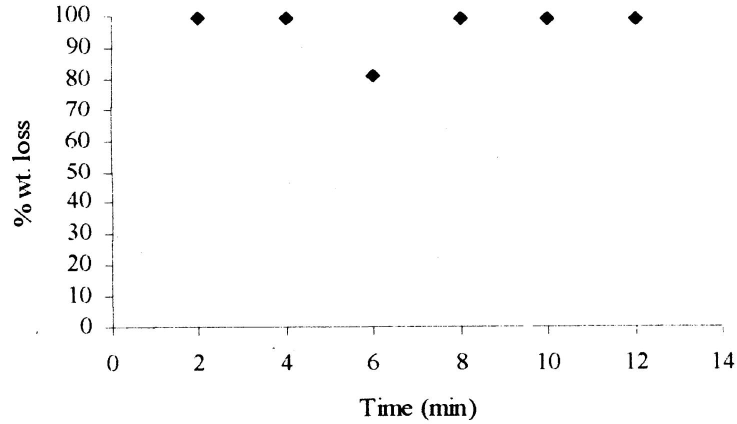

Fig. 5. Per cent weight loss w.r.t. time for cauliflower

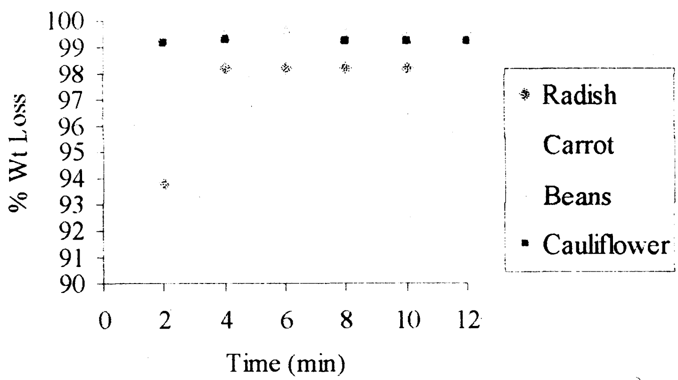

Fig. 6. Comparative weight loss of biomass samples

Residue Analysis

The residue obtained was analyzed for its carbon content and volatile matter content. The residue analysis was of specific importance for disposal if the waste is to be incinerated. Incinerators for solid waste with grate normally have two chambers and the first chamber is kept at 800°C. Hence, the residue analysis was attempted at 800°C.

(1) Carbon content: The residue was kept at 800°C for 1 h and its % weight loss was plotted against time. The % weight loss *vs.* time curve indicated that the material still needed about 10 min of burning before all the carbon was combusted as indicated in Figs. 7 and 8. This shows that all these residues follow the same pattern when combusted at 800°C.

(2) Volatile matter: Volatile matter in the ash was determined by keeping the ash at 850°C for 7 min in closed crucibles. It was calculated to be approximately 15% in all cases.

(3) Study at 800°C showed that the residue of the biomass samples take additional 10 min for complete combustion and to produce white ash in presence of sufficient air (Fig. 7).

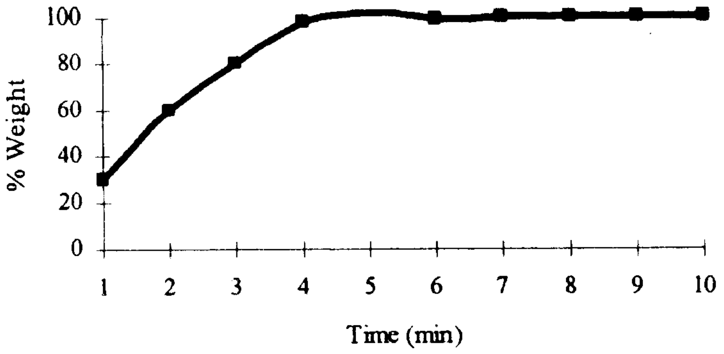

Fig. 7. Weight loss *vs.* time for ash combustion

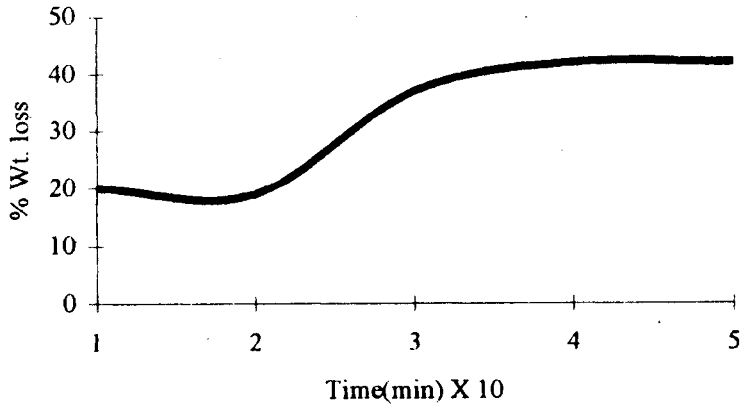

Fig. 8. Combustion of residue of fruit peel with time at 800°C

Conclusions

The laboratory experiments showed that these biomass wastes need sufficient air and at least 40 min for complete combustion. Hence, sufficient residence time must be given during thermal degradation for complete destruction and to produce white ash, which could be disposed of safely in an environment friendly manner.

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