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Research Article

DETERMINATION OF THE LEVELS OF INORGANIC ELEMENTS IN ASHES FROM SELECTED AGRO-WASTE BIOMASS FROM GITHURAI MARKET, NAIROBI, KENYA

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ABSTRACT
The ashes from different types of agricultural wastes from Githurai market in Nairobi County and rice husks from Mwea Rice Irrigation Scheme in Kirinyaga County have been analyzed for their inorganic elements using both atomic absorption and x-ray fluorescence spectroscopic techniques. The selected biomasses were cleaned thoroughly with water, dried and subjected to combustion in a furnace maintained at 560ºc for 8 hours to produce ashes. The results of this study indicates that some biomaterials contains very high levels of K_2O and Na_2O, for instance ashes from banana, potato and pineapple peelings were found to have high concentration of K_2O at 63.17±0.09%, 59.48±0.77% and 47.05±0.30% respectively. These were however recovered as the carbonates and therefore explain why; ashes were used by the ancients for the manufacture of soap. The ashes from onion stalk waste and pigeon pea pods had high levels of CaO at 34.95±2.28% and 15.20±5.74% respectively. Rice husks and banana leaves ashes were found to contain over 97% and 67% silica respectively which are important raw materials for pozzolanic cement production. The results of the research study show that the current practice of burying ashes from biomass is therefore not advisable since they could be treated as starting resources for other important products rather than being disposed off as waste.

Keywords: *Biomass, Municipal Solid Waste, Biomass Waste, Landfill, Ash*

INTRODUCTION
Biomass is any material of organic origin such as trees, grass, agricultural crops or other biological materials. Biomass waste can be used as solid fuel or be converted into liquid or gaseous form for the production of electrical power, heat, chemicals or fuel (Bain, 2004). It is a renewable energy source because we can always grow more trees and crops and thus raw material residues will always be available (Bothum, 1998).

Globally, the amount of biomass produced each year through photosynthesis is vast. It has been estimated that net annual photosynthetic production of organic matter amounts to roughly 2×10^{11} tonnes; equivalent to 3×10^{21} joules of energy, which is approximately 10 times the present World energy consumption (Hall *et al.,* 1982).

Biomass based energy raw materials can be categorized into: natural vegetation, energy crops and organic waste products from industrial, domestic or agricultural resources (Schumacher *et al.*, 1985). Biomass energy resources can also be classified into five main categories namely: wood, crop residues, animal manure, household wastes and food waste (Hall *et al.,* 1982). Another source of biomass is garbage generated in towns and cities which is part of what is referred to as Municipal Solid Waste (MSW) (Bothum, 1998).

Municipal solid waste is generated as a result of various human activities in urban areas. The term "waste" is however, inappropriate here because several economically useful materials can be recovered from MSW. Examples of such materials include ferrous and non-ferrous substances such as metals, polythenes, broken glasses/bottles, lead batteries, paper, bones, fruits and vegetable peelings.

Solid Waste Collection in Nairobi
In 1999, Nairobi had an estimated population of 2.2 million people with an estimated growth rate of 4 - 5% per annum. Japan International Cooperation Agency (JICA) report of 1998 placed the production of

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refuse in Nairobi at approximately 1,530 tonnes per day. The report further showed that 360 tonnes of solid waste were collected per day, or about 25% of the total amount of waste generated in the city. Of this, NCC collected 22% and private firms collected 32%. On average, about 61% of the collected solid waste came from residential areas, 21% from industrial areas and 6% from roads (ILO, 2001).The figures may be very high at present.

Low-income areas and informal settlement are poorly serviced by waste collection services. Fig. 1 below shows the comparison in provision of solid waste collection services in different parts of Nairobi and its environs.

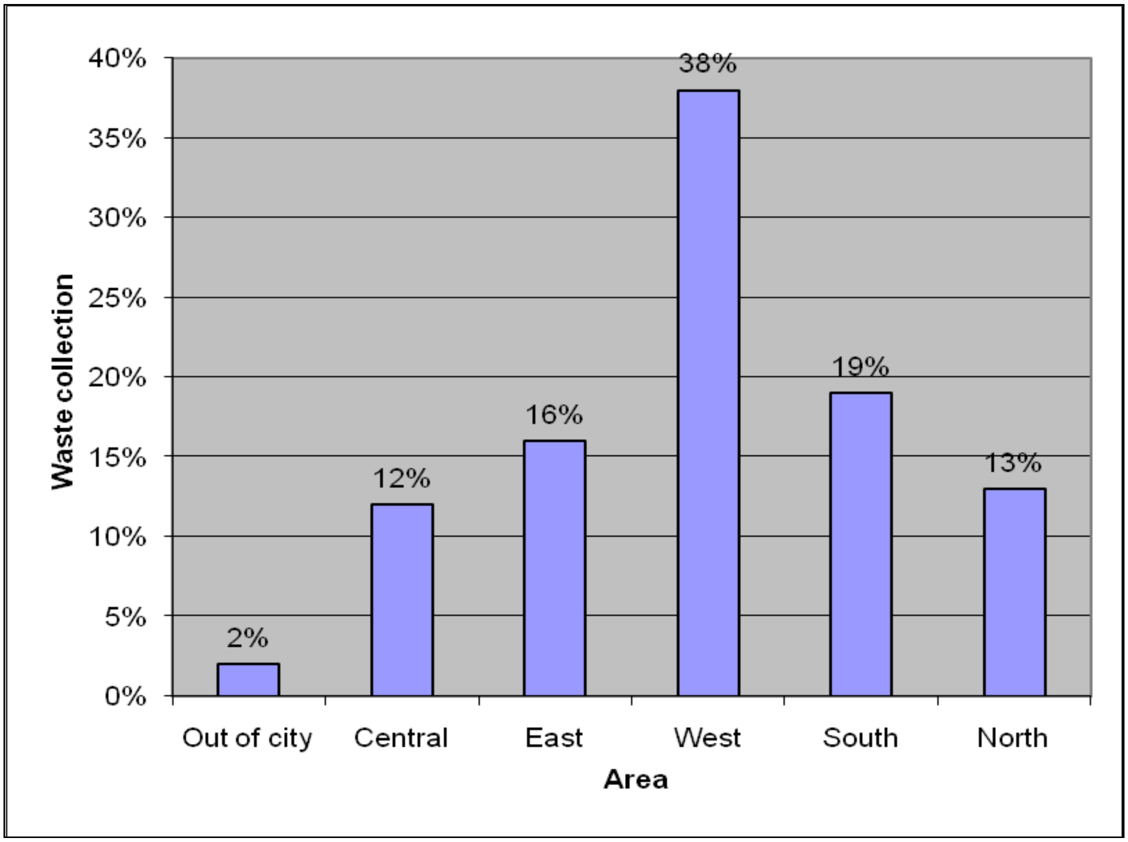

Figure 1: Distribution of solid waste collection services in different parts of Nairobi (JICA, 1998)

It is estimated that between 50 - 75% of the garbage remains uncollected and thus rots close to its source. The rest of the waste is carted into a dumping ground on the arid plains to the south of the city, out of sight and out of mind, where the voiceless majority reside, Dandora dumpsite which was established by the county government of nairobi in the mid-1980's (Kantai, 2000). In general, regular private waste collection services are provided in most high income areas. In the middle-income areas, waste is poorly managed with open dumping and burning being a common sight on open spaces and along the roads. Communal containers and refuse in these areas overflow with garbage resulting in the presence of pests and obnoxious odours. In low-income areas and informal settlements, open dumping and burning of waste along roads is widespread with bad odour, pests and scavengers being common characteristics (ILO, 2001).

Composition of Waste

The JICA study showed that out of 1,530 tonnes of garbage which were however collected per day in Nairobi, the following composition of waste was realized: food waste 51.1%, paper 17.3%, textile 2.7%, plastic 11.8%, grass/wood 6.7%, leather 0.9%, rubber 1.5%, glass 2.3%, metal 2.6% and others 2.7% as shown in figure 2.

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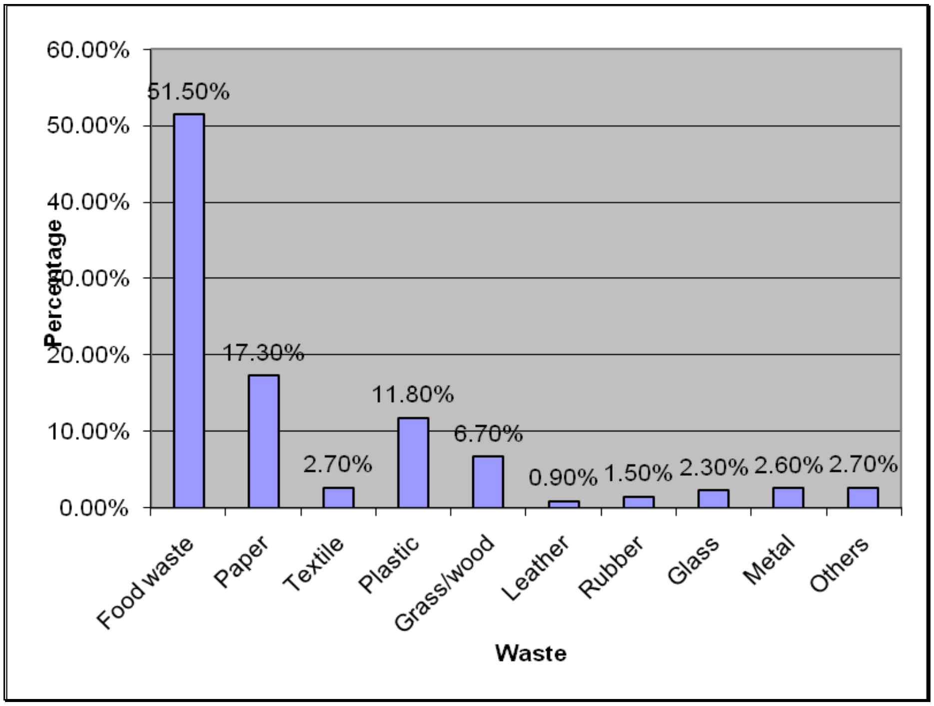

Figure 2: Composition of solid waste collected in Nairobi (1998)

Recyclable materials such as plastics, paper and glass make up a significant percentage of the waste in Nairobi. The trend is that most of the recyclable waste is found in middle and high income areas. The waste in low-income areas is largely composed of petrucible organic matter suitable only for compost production (ILO, 2001).
Biomass wastes are solid organic residues, surplus and by-products of agro-industrial processing available in bulk. In Kenya, biomass wastes produced in large quantities include: coffee husks, tea wastes, maize cobs, rice husks and saw dust among others. In urban areas, agro-wastes are mainly contributed by foodstuff such as vegetables and fruit peelings (Kibulo and Owen, 2004). The quantity of residues produced in a year easily exceeds the production of crop itself (Barnard *et al.,* 1985)**.** It has been shown that only 5% of plant total biomass is suitable for food. The remaining 95% can be used as animal feed, soil conditioning, building material and fuel (Hankins, 1987). Biomass continues to be a major source of energy in the World today. In the developing countries for instance, biomass accounts for about 70% of the energy generated. In Kenya, for example, Mumias Sugar Company currently uses baggase for generation of electricity. Additionally, Clayworks Limited in Nairobi buys coffee husks from Kenya Planters Cooperative Union (KPCU) for firing bricks and tiles. A method of making charcoal briquettes from coffee husks has been developed by KPCU. The charcoal is sold in shops rather than by the roadside and is claimed in its advertisement to have "3 times heat content than ordinary charcoal." In 1984, more than 36,000 tonnes of these briquettes were exported to the Middle East (Foley, 1986).
Currently, biomasses are recycled in the following ways:
1. Easily decomposable materials such as fruits and vegetable peelings are converted into compost manure
2. Biomass can also be dried, and heated in absence of air to make charcoal
3. Biomass can also be dried and burned to generate steam at very high pressure which turns turbines hence generating electricity
4. Some items such as glass, paper, plastic, metals are recycled to generate income for those involved
5. Other solids are placed in well-engineered landfills (Zerbock, 2003).
By definition, an ash is an inevitable product of the combustion of solid fuel while biomass ash is the residue from the combustion of plant biomass which is increasingly being used for the production of heat

and electricity. It can be viewed as a waste to be disposed off; however, it also contains valuable minerals and can be used as fertilizer among other uses. When biomass is burnt, the ashes are buried as waste. Unfortunately, when it rains, heavy metals in the ashes are washed down and thus contaminate ground water (Williams *et al.,* 1994). The problem is particularly bad when the biomass is mixed with industrial waste having metallic components.

MATERIALS AND METHODS

Reagents and Instruments

All chemicals used in this study were obtained commercially and used as received unless otherwise stated. Distilled and/or distilled water was used throughout the study. Weighing was done using an electronic balance model AAA 160/L from Adam Equipment Company Limited. Most of the samples were collected from Githurai market; about 15 km from Nairobi city centre along Nairobi-Thika Highway and rice husks were obtained from rice mills in Mwea area, Kirinyaga County.

Sample Treatment

The samples were sorted out properly to remove any foreign matter such as stones and soil. They were cut into smaller pieces, cleaned thoroughly with distilled water, followed by rinsing with distilled-deionized water.

All samples were then dried in an electric oven at 110º C for at least 2 - 3 hrs to remove moisture and then cooled in a desiccator as described by Vogel *et al.,* 2000.

Ashing Process

Twenty grams (20 g) of well-mixed air-dried biomass samples was accurately weighed into each of the six dry porcelain crucibles. The masses of the dry crucibles were recorded before adding the biomass and the total mass recorded. This was then heated slowly in a furnace while raising the temperature settings in steps (100ºC, 200ºC, 270ºC and 560ºC). The temperature of 270 ºC was maintained for 8 hrs, cooled and weighed to give the loss in mass of volatile matters. The final temperature setting of 560 ºC was also maintained for 8 hrs. The crucibles containing the grayish-white ash were then cooled in a desiccator and weighed to determine the mass of both the ash and the amount of carbon burnt. The % ash was calculated using the Okalebo *et al.,* 1983 protocol by difference in weight of the crucibles before and after combustion as follows:

$$\%\ \text{ash} = \frac{W_4 - W_1}{W_2 - W_1} x 100\% \qquad (2.1)$$

$$\text{Mass of carbon burnt} = W_{3-} W_4 \qquad (2.2)$$

$$\text{Organic matter} = 100\% - \%\ \text{ash} \qquad (2.3)$$

Where;

W_1 = mass of empty, dry crucible
w2 = mass of dry crucible + dry biomass
w3 = mass of dry crucible + cooled carbonaceous solid
w4 = mass of dry crucible + cooled greyish white ash

The ashes were then homogenized and put in self-sealing polythene bags, labeled and stored in a dry dust proof drawer under lock and key to a wait analysis process.

Sample Preparation for X-Ray Fluorescence Spectrophotometry

Exactly 10g of each ash sample was accurately weighed and mixed with 5g of the starch, placed in a suitable die and compressed to obtain a flat cylindrical pellet. After drying, total elemental analysis was carried out to determine all the elements presents in the ashes in form of % oxides (Townshend *et al.,* 1995).

Digestion of the Ashes

The ashes were dried in an electric oven at 110^oC for 2 hours, cooled in a descicator. About 0.12g of each ash sample was accurately weighed into 100mL glass beakers and digested with aqua regia (1:3 V/V HCl and HNO_3) with constant heating in a fume cupboard until a clear solution was formed. Excessive heating was avoided as it could cause spattering. Samples were then filtered using a Whatman No. 41 ashless filter paper into 100 mL volumetric flasks. 4mL of strontium chloride solution was added to each sample to release phosphate during calcium determination. Each filtrate was then adjusted to the mark using deionised water for AAS and Flame photometry analysis. This procedure was repeated three times for each sample. Ashes were analyzed immediately or stored in plastic labeled containers at 4^oC until analysis was set up (Cid *et al.*, 2001).

RESULTS AND DISCUSSION

When biomasses containing a lot of moisture, such as banana or pineapple peels were dried at 110 °C, only about 10% of the original mass was left. An important implication of this observation is that in the transportation of such biomasses, a lot of expenses are incurred in transporting such water in the biomass. When the ashes were put in water, some materials dissolved, making the solution strongly alkaline. This was however, a quick interpretation to mean that there is the presence of both sodium carbonate and potassium carbonate in the ashes, an observation that was confirmed when the ashes were treated with dilute hydrochloric acid, whereupon a strong effervescence of carbon (IV) oxide took place.

Levels of Inorganic Elements by XRF analysis

Table 2 below gives an assay analysis done on various samples of ashes of selected biomass waste.

Table 1: Percentage of the elements as oxides

Sample species	Na_2O	MgO	MnO	P_2O_5	K_2O	CaO	SiO_2	Al_2O_3	TiO_2	Fe_2O_3
Orange peelings	7.45	1.53	0.041	2.56	33.69	28.05	0.05	1.51	0.30	0.51
Pigeon pea pods	14.69	4.90	0.21	3.76	40.46	12.83	4.54	1.64	0.22	1.73
Pineapple peelings	8.34	0.44	0.53	5.08	43.93	2.68	7.50	1.20	0.08	1.00
Rice husks	bd	bd	0.13	bd	0.98	1.36	97.40	2.97	bd	0.44
Banana peelings	6.48	0.03	0.16	2.75	59.08	2.52	3.33	1.80	0.07	0.44
Kales stalks	14.43	1.75	0.03	1.46	38.02	13.32	0.06	1.96	bd	0.46
Garden pea pods	20.51	5.27	26.41	4.85	26.41	23.36	0.01	0.98	0.04	0.96
Potato peelings	10.50	1.28	0.06	7.21	56.47	2.56	Bd	1.45	0.09	1.29
Banana leaves	1.89	0.61	2.60	1.63	9.87	8.68	61.61	1.98	0.01	0.70
Onion stock waste	6.44	1.86	0.28	0.86	7.02	40.14	5.19	2.85	0.28	2.27

***Key:** bd = below detection limit*

The results show that some ashes contain relatively high levels of many essential elements with potential for recovery for example; the oxides of sodium and potassium are present at very high levels in some of the biomaterials. Potassium oxide, K_2O was generally high in most of the materials except in rice husks ashes where its concentration was 0.98%. Banana peelings, potato peelings, pineapple peelings, pigeon pea pods, kales stalks and orange peelings had the highest levels of K_2O at about 59.08%, 56.47%, 43.93%, 40.46%, 38.02% and 33.69% respectively. Onion stock waste, orange peelings and garden pea pods had relatively high levels of calcium oxide at 40.14%, 28.05% and 23.36% respectively. Silica was quite high in rice husks and banana leaves at 97.40% and 61.61% respectively. Other materials had much lower percentage of silica. Orange peelings and banana peelings had combined alkalis of about 41.00% and 65.00% respectively. Table 2 below shows the overall results obtained from the atomic absorption spectroscopy and flame photometry.

Table 2: Summary of elemental analysis in percentages by AAS and Flame Photometry

Samples	K_2O	Na_2O	MgO	CaO	FeO
Orange Peelings	29.42 ± 3.41	13.88 ± 1.40	1.73 ± 0.02	6.32 ± 0.12	0.14 ± 0.01
Pigeon Pea Pods	38.77 ± 1.05	10.48 ± 0.87	0.35 ± 0.07	15.20 ± 5.74	$0.83 \pm .05$
Pineapple Peelings	47.05 ± 0.30	12.89 ± 0.72	1.37 ± 0.09	5.33 ± 2.28	0.84 ± 0.04
Rice Husks	0.49 ± 0.03	0.45 ± 0.03	0.86 ± 0.11	0.98 ± 0.09	0.10 ± 0.01
Banana Peelings	63.17 ± 0.69	16.29 ± 0.54	1.06 ± 0.09	1.53 ± 1.32	0.14 ± 0.01
Kales Stalks	35.47 ± 0.78	14.35 ± 0.51	1.04 ± 0.06	4.92 ± 0.32	0.09 ± 0.01
Garden Pea Pods	25.29 ± 0.73	9.71 ± 0.80	1.79 ± 0.03	5.62 ± 0.11	0.50 ± 0.06
Potato Peelings	59.48 ± 0.77	15.78 ± 1.56	1.41 ± 0.02	2.29 ± 1.32	0.65 ± 0.06
Banana Leaves	6.85 ± 0.77	1.20 ± 0.18	0.28 ± 0.02	6.85 ± 1.32	0.27 ± 0.03
Onion Stalk Waste	2.58 ± 0.19	4.30 ± 0.65	0.86 ± 0.19	34.95 ± 2.28	1.04 ± 0.04

As is well known ashes has been used for soap-making for many centuries as, in Babylon where records dates back to 2800 BC (htt://www.alcasoft.com/soapfact/history.html.). No doubt, this was because of the alkalinity of the ashes. There are two major reasons as to why alkalis are important. First, is in minerals processing as of chromites (Johnstone and Johnstone, 1961) which require fusing with an alkali to convert the element being extracted into a soluble form. Both sodium carbonate and potassium carbonate are used as fusion mixtures. Second is in the manufacture of glass, silica is fused with either soda ash (Sreve *et al.*, 1977) or potassium carbonate. Recently, scientists have investigated the medicinal impact of bananas and plantains on stomach ulcers and there have been claims that bananas may stimulate cell and mucus production in the stomach lining.

By thickening the stomach walls and sealing its surface, they may help to heal existing ulcers and stave off new ones. However, there is yet very little evidence to support the claims. Bananas are indeed a good source of potassium, which is a vital mineral for muscle and nerve function. Potassium also helps to regulate blood pressure. They contain a high level of natural sugar which they release quickly into the bloodstream when needed (Bosibori, 2015). In our view, ashes contain useful minerals which can be utilized in various ways instead of burying them as waste

Conclusion

The results of this study reveals that ashes from the burning various types of biomasses which are currently being treated as a wastes, are an important source of many essential elements for both plant and animal life. There is need to extract the elements after determining their percentage concentrations from each biomass sample since the disposal of such ashes in form of waste only increases environmental pollution.

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