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Research article

SOLID WASTE MANAGEMENT- CASE STUDY OF NDOLA, ZAMBIA

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ABSTRACT: The study was carried out in Ndola, the provincial capital of the Copperbelt province of Zambia with the aim of evaluating the methods of solid waste disposal, the level of access to solid waste management services, and Ndola residents' attitudes towards solid waste management. 60 households were randomly selected for the administration of questionnaires and collection of household waste. The results showed that there is an inadequate solid waste management facility in Ndola even though up to 80% of households in medium density areas indicated willingness to pay for waste collection and disposal services. The solid waste collected in this study comprised mainly food waste (50% of household waste in low density areas and 45% in medium density areas), while paper and textiles were the least abundant in the household wastes evaluated. The C: N ratios of the wastes collected ranged from 16.21 to 27.06 a range indicating that the waste will be good material for use as compost. The lack of environmentally friendly, sustainable and affordable waste management has led to the wide spread open dumping and open burning of solid waste. This calls for concerted efforts at increasing efforts towards waste minimization, utilization and management.
Keywords: Municipal waste, Solid waste, Household waste, Ndola, Waste management, Waste disposal

INTRODUCTION

Solid waste is defined as the waste arising from human and animal activities that are normally solid and that are discarded as useless or unwanted [1]. The generation of solid waste is on the increase due to rapid rise in population, changing life styles and popularity of fast foods and disposable utensils. Waste generation has been increasing enormously at an average annual rate of 8.96% [2]. In Lusaka the annual average amount of solid waste has been increasing and is expected to grow from 220, 000 tons recorded in1996 to 530, 000 tons in 2011, an increase of 141% [3]. The resulting effect is that the task of managing solid waste has become an enormous challenge for the institutions charged with the responsibility of solid waste management. Limited resources in terms of money, skilled manpower and logistics make it very difficult to handle the bulk volume of solid waste being generated.

Solid waste in urban areas is generated by domestic sources, street sweeping, hospitals, commercial and industrial activities [4]. Only a fraction of this solid waste is collected and disposed off at designated sites. The remaining uncollected solid waste is left on the streets, roadsides and drainages. They run into waterways when it rains and this has resulted in several outbreaks of cholera and other diseases associated with improperly disposed solid waste. In addition, they contribute to general deterioration of the environment especially in the peri-urban areas and adjoining high density areas. The need for an environmentally acceptable waste management strategy has become an urgent issue in Zambia [3].

Ndola is 321 km from Lusaka, the capital city of Zambia (Fig. 1). This city used to be the most industrialized in Zambia, housing big companies like Zambia Sugar, Zambia Copper Consolidated Mines (ZCCM), Dunlop and other companies. Previously, solid waste was collected from residential areas at no cost to households. The Ndola City Council (NCC) could afford a free collection and disposal of solid waste due to a vibrant city economy. Besides, companies like ZCCM, had their own solid waste collection and disposal systems.

The change of government in 1991, which ushered in the 3rd republic, saw a drastic shift in public policy from socialism to capitalism. Companies were privatized or folded due to lack of capacity to compete with imports. The borders were opened for international trade. This reduced the Council's revenue base. Solid waste management completely collapsed in 2000 when ZCCM was privatized. The new owners were not interested in solid waste collection and disposal. They wanted to concentrate on the core business of mining.

The Council was overstretched and failed to cope up with the situation. Since then the economy has been shrinking and the Council has found itself with less and less resources to spend on waste collection and disposal. The Council had 15 trucks for solid waste management in the 70's, but by 2001 the number had reduced to only one.
This created a vacuum, for the first time there was the mushrooming of small scale medium entrepreneurs, who started collecting solid waste from residential areas at a fee. But they are less that 30, in fact only 9 are registered with the Environmental Council of Zambia (ECZ) [5] and they are not enough to cover the city. In 2003, the NCC embarked on a community based solid waste management project sponsored by the United Nations to implement a pilot system that links informal micro-enterprises to environmental protection through improved waste minimization, efficient collection, promotion of waste recycling, reuse, environmentally sound disposal methods and effective use of land fill. The project however failed to sustain itself and spread to other areas. In 2004, the Council acquired some solid waste collection trucks and other equipments through a Japanese grant and by 2007, system was working effectively but there are still wastes on the streets until now.
This study therefore sought to investigate the causes of non-compliance of households with waste management strategies by government and to offer solutions to same for a cleaner and safer environment in Ndola.

MATERIALS AND METHODS

Study areas and sampling

Three sampling areas were selected in the study site (Fig. 1). These were – Kanseshi (a low density area), Skyways (a medium density area) and Kabushi (a high density area). To avoid bias in sample selection a random probabilistic procedure was used to select the study locations. This involved using specially prepared tables called random numbers. Since the sampling areas are geographically isolated, stratified sampling, which is suitable when populations are divided into locations e.g. high density, medium density and low density was used. To select the sampling areas, all the names of a high density areas were coded in 2-digit figures (i.e. 01, 02, 03 etc). Starting at any haphazardly chosen point, successive numbers in the same direction were read until one coded digit came up. The corresponding area was then recorded as the selected sample area in the category of high density area. This was repeated for the medium and low density areas. Twenty households were selected in each study area using this table of random numbers.

Fig. 1. Ndola Province of Zambia

Primary data acquisition

For each of the 60 households selected for this study, questionnaires were administered to evaluate the attitudes of households toward solid waste management (Table 1).

I am a fifth year student at the Copperbelt University, School of Technology conducting a research on the above mentioned topic. The information that will be collected is purely for academic purposes and it will be dealt with strict privacy

1. Solid waste constitutes a serious health problem in Ndola. ◊ Strongly agree ◊ Agree ◊ Disagree ◊ Strongly disagree ◊ Not sure	8. How often is the refuse collected? ◊ More than once a week ◊ Once weekly ◊ BI weekly ◊ Other (Please Specify..........................)
2. Waste collection and disposal is the sole responsibility of the Government. ◊ Strongly agree ◊ Agree ◊ Disagree ◊ Strongly disagree ◊ Not sure	9. How much do you currently pay for waste management services? ....
3. Solid waste management contributes largely to cleanliness in Ndola. ◊ Strongly agree ◊ Agree ◊ Disagree ◊ Strongly disagree ◊ Not sure	10. Do you think this is reasonable? ◊ Yes ◊ No ◊ Do not know
4. I am willing to participate in proper disposal of wastes generated in my home. ◊ Strongly agree ◊ Agree ◊ Disagree ◊ Strongly disagree ◊ Not sure	11. Are you satisfied with the services? ◊ Yes ◊ Yes but ◊ No
5. It is not necessary to have a waste bin in the home. ◊ Strongly agree ◊ Agree ◊ disagree ◊ Strongly disagree ◊ Not sure	12. If no, how do you dispose the solid waste you generate? ◊ Back yard dug out pit ◊ Dump outside the yard Other (Please specify)...
6. Do you receive the solid waste management services ◊ Yes ◊ Sometimes ◊ No	13. Are you willing to pay for solid waste services if they are introduced in your area? ◊ Yes ◊ Yes but No
If answer to question 7 is “no” go straight to 12 and 13 7. If yes, who provides the solid waste management services ◊ Ndola city council ◊ Copperbelt solid waste management company Private Service provider (Specify name................................)	

Waste collection
Each household was given five labeled plastic container for food waste, plastics, paper, textile, grass and other wastes like ceramic, glass and metals. Every week the wastes were hand-sorted, weighed by category and the results recorded. This was done for a period of one month.

Waste analyses
Municipal solid waste collected from study households were analyzed for weight, moisture, density, volatile matter, fixed carbon, ash and sulphur.

Physical Composition of Waste: Determination of waste composition was by physical separation and visual observation of collected wastes. Each bag of waste was weighed and then its contents emptied and separated before notes were made of all the different types of waste that constituted each class of waste.

Determination of Density: Estimation of the density of waste sample was calculated using the following formula: Density (kg/m^3) = Mass / Volume of waste

Determination of moisture: The samples were prepared in duplicate by weighing 5g of the domestic solid waste in a dish. The dish was placed in an oven at 105ºC for one hour after which it was placed in the dessicator to cool and then re-weighed. The procedure was repeated until a constant weight was recorded. Moisture content of the sample was then calculated as:

% moisture = loss in weight × 100/ weight of sample.

Determination of ash: The samples were taken in duplicates of 5g each and ignited to heat up to 400ºC with gradual increase in temperature of the muffle furnace to 800ºC for one hour. The dish was removed from the muffle furnace and quickly placed in the dessicator. The dish was allowed to cool before the residue was weighed. The ash content of the sample was calculated as: % ash = weight of the sample × 100 / weight of the sample.

Determination of volatile matter: The samples were prepared in duplicate and 5g of domestic waste placed in a crucible. The crucible with its content was placed in the muffle furnace at a temperature of 950ºC, and heated for exactly seven minutes, timed with a stop watch. The crucible was then removed from the furnace and placed in the dessicator. After cooling the crucible with its content were weighed accurately and volatile matter calculated as:

% volatile matter = loss in weight × 100 / weight of sample – {% moisture}

Calculation of fixed carbon: Fixed carbon was obtained arithmetically as follows;

% fixed carbon = 100 – {% ash + % volatile matter}

Estimation of sulphur content: The ash obtained was extracted with dilute HCl, and then treated with $BaSO_2$. The precipitate of $BaSO_4$ formed was filtered, dried and weighed. The amount of sulphur in Wg of sample = $\{32 \div 233\} \times \{W_c \div W_{ppt}\}$.

RESULTS AND DISCUSSION

The percent physical composition of wastes generated from the different locations examined is presented in Fig. 2. Food waste was found to be the most abundant of wastes from the low density area, comprising about 50% waste generated in that area. This was followed by 45% from the medium density area and 25% in the high density. Paper waste generated was the same in all the three areas at 5%. Plastics represented 10% of waste generated in low and medium density areas and 5% of waste generated in the high density area. Garden waste made up 30% of waste produced in the low density area while the medium and high density produced 20 and 30% garden waste respectively. 2% of wastes obtained in the low and medium density areas were textile waste, while the high density generated 5% textile waste. The high density area generated more of other wastes including ceramics, metal, glass, dirt and wood which are generally present in municipal waste in varying proportions relative to local factors. These made up 20% of waste generated in that area, followed by the medium density and low density at 18% and 3 % respectively. These values are generally comparable to those observed by previous workers [6, 7].

Compositional analysis of municipal solid waste is difficult at national scale because of the availability of a wide array of waste analysis methods, sample selection techniques and waste streams to be covered [8, 9, 10]. Time trends are believed to be more feasible if repeat-sample at individual community levels are analyzed as done in this study.

The observed trend is quite typical of current trends in municipal solid waste, with food waste comprising the largest percentage. However, contrary to earlier reports, garden waste and not paper was the next most abundant waste generated by households. In addition, the quantities of plastic wastes were generally higher than for paper, a trend different from that summarized by Holmes [11].

Table 2. Per capita waste generation per day (kg) by household category

Type of waste	Low density		Medium density		High density	
		%		%		%
Food waste	0.30	50	0.23	45	0.11	25
Paper	0.03	5	0.25	5	0.02	5
Plastic	0.06	10	0.50	10	0.02	5
Garden waste	0.18	30	0.10	20	0.18	40
Textile	0.01	2	0.01	2	0.02	5
Others	0. 02	3	0.09	18	0.09	20
Total	0.60		0.50		0.45	

This indicates that there are changes in the composition and quantity of waste due to changes in lifestyles, trends and household preferences. This information is significant for future planning of waste management. The results obtained by Gidarakos *et al* [12] showed that there has been a significant decrease in organic wastes during the last decade due to the increase of packaging materials, as a result of a change in consumption patterns. The authors also found a strong correlation of waste composition with certain human activities, such as tourism reflected by an increase in paper and/or plastics packaging materials characteristic of intense tourist activities.

Table 2 shows the per capita waste generation per day (kg) of the different types of wastes by household categories. The overall generation rate for the city of Ndola (planned settlement) as a whole was 0.52 (calculated from total per capita values). This value was in the range recorded by Holmes [11] for waste generation (kg/cap/day) in low income countries. Waste generation, both domestic and industrial, continues to increase world-wide in tandem with growth in consumption. In developed countries, per capita waste generation increased nearly three-fold over the last two decades, reaching a level five to six times higher than that in developing countries. With increases in populations and living standards, waste generation in developing countries is also increasing rapidly.

The chemical composition of solid waste collected from the study areas is shown in Table 3. The density of solid waste ranged from 131kg/m^3 in the high density area to 152kg/m^3 in the medium density area, while wastes from low density had a mean value of 144kg/m^3. The significance of density in municipal solid waste is that it enables the managers to plan and identify the capacity of waste haulage vehicles and management strategies to be used. Waste moisture contents obtained ranged from 25.52 to 37.31%, values lower than those observed by Carboo and Fobil [6] in Accra metropolis, Ghana.

The carbon and nitrogen values observed were comparable to those of common recyclable wastes like legume hay, wood chips and cow manure indicating that the wastes have capacity for use as compost or organic fertilizer. The carbon to nitrogen (C/N) ratios ranged from 16.42 in low density areas to 27.32% in high density areas (Table 3).

Table 3. Chemical composition of municipal solid waste in Ndola

Parameter	Low density	Medium density	High density
Density kg/m3	143.45±0.61	152.13±0.76	138.67±0.42
%Moisture	37.31±0.34	32.85±0.49	25.52±0.57
% Ash	7.57±0.08	11.53±0.41	16.24±0.34
% Volatile matter	73.67±0.56	62.78±0.26	42.30±0.44
% Fixed carbon	18.40±0.30	25.36±0.32	40.99±0.24
% Nitrogen	1.12±0.12	1.63±0.04	1.53±0.04
C:N Ratio	16.42±0.32	19.51±0.36	27.32±0.38
% Sulphur	0.16±0.03	0.12±0.03	0.10±0.04

Legend: Values are means ± standard deviation

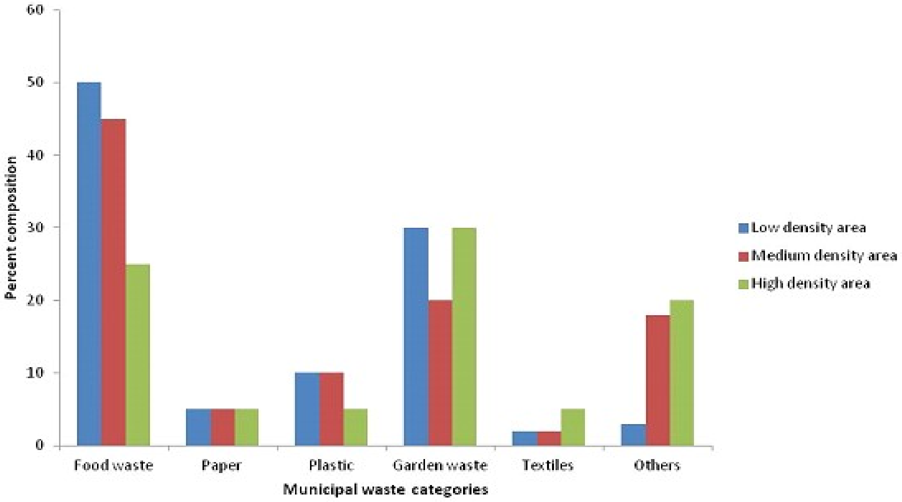

Fig. 2. Physical composition of municipal solid waste categories in Ndola

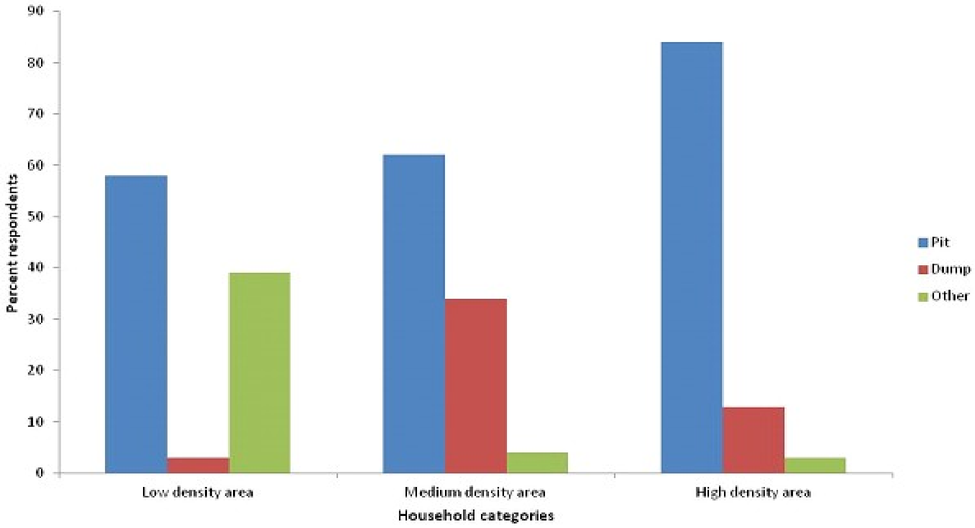

Fig. 3. Solid waste disposal methods used by households in Ndola

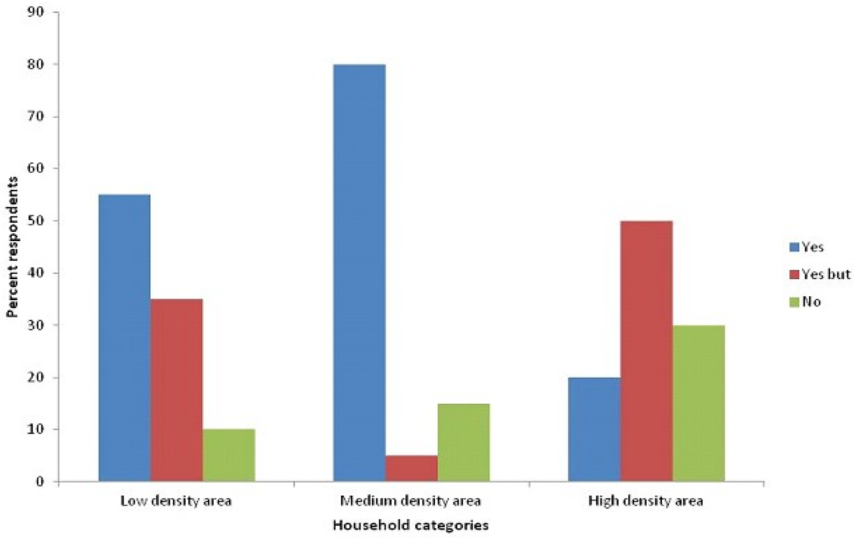

Fig. 4. Willingness of Ndola residents to pay for governmental municipal solid waste management services

However the most adaptable C/N ratio for composting was from low density area waste which was in the order of <20:1, a value range that encourages the release of mineral nitrogen early in the decomposition process. Carbon to nitrogen ratio is important for determining the suitability of the solid waste for composting and the typical average value of C/N ratio is 25.66. The C/N ratios observed in this study are comparable to those reported by previous studies [13, 14]. For example, the range of C/N ratio in Indian Municipal Solid Waste was found to be 21.13-30.94. When C/N >30, there is loss of nitrogen through immobilization during composting. Composting time is also known to increase with higher C/N ratios.

The results of the survey showed little variations ($p \leq 0.05$) in the opinions expressed by respondents from low density, high density and medium density areas except for the question on possession of bins in the home. All the respondents in the high density, low density, and medium density areas strongly agreed that solid waste constituted a serious health problem in Ndola. The majority (76%) also agreed that waste collection and disposal was the sole responsibility of the government and that improper solid waste management contributes to poor hygiene of the city. Use of rubbish pits was the most common method of waste disposal employed in the low and medium density areas (Fig. 3). On the other hand there was a wide variation in the way residents responded on willingness to participate in proper disposal of waste generated in their homes by paying for waste collection services (Fig. 4).

Municipal wastes are mainly derived from households, institutions and commercial areas. These wastes pose the most alarming problems in urban areas such as Ndola, the study area because the current management strategies by the local authorities are inadequate. Often a discrepancy exists between the growing population in urban areas and the increasing demand for sanitation and solid waste collection services on one hand and the capacity of the local government to provide these services on the other hand [15]. As a result, solid waste disposal remains one of the biggest environmental concerns worldwide. Government policy on solid waste reduction has relied on voluntary measure by waste generators at all levels of the economy, and within this policy framework, local authorities have an important role to play in the way they manage wastes locally.

CONCLUSION

Information on the nature of solid household waste, its composition, physical and chemical characteristics have been provided by this study. Such information contributes to the much required database available to the responsible governmental agencies for the planning of an effective and efficient Solid Waste Management system.

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