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Municipal Solid Waste Generation, Recovery and Recycling: a Case Study

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ABSTRACT [ENGLISH/ANGLAIS]

The paper presents a case study focused on waste generation, material recovery, and the recycling potential of municipal solid waste in Maiduguri, Nigeria. The municipal solid waste (MSW) generation was estimated using a fuzzy logic based mathematical model followed by a collection scenario thought of, adopted and tested within two planned residential areas; the University of Maiduguri campus and the 202, 303 housing estates of the Maiduguri metropolis. Data obtained were analyzed using simple statistical methods. The mathematical model predicted 255 tonnes of MSW against 226.63 tonnes by collection estimates. An important amount of recyclable materials was found to be generated within the study area. Incurred fuels expenses on the trucks alone, do exceed the monthly wages of 400 waste collectors. MSW collection, material recovery and recycling are alternatives to fight poverty, and contribute immensely towards social re-insertion of marginalized people. Further research is needed on the waste production equation for estimates of waste generation in not well planned areas.

Keywords: Municipal solid waste, generation, modelling, fuzzy logic, recovery, re-use, recycling, economy

RÉSUMÉ [FRANÇAIS/FRENCH]

Le document présente une étude de cas centrée sur la production de déchets, la récupération des matériaux, et le potentiel de recyclage des déchets solides municipaux à Maiduguri, au Nigeria. Les déchets solides municipaux (DSM) génération a été estimée en utilisant une logique floue basée modèle mathématique suivie d'un scénario de collecte pensé, adopté et testés dans les deux zones résidentielles prévues, l'Université de Maiduguri campus et les 202, 303 lotissements de la métropole Maiduguri . Les données obtenues ont été analysées à l'aide de méthodes statistiques simples. Le modèle mathématique prédit 255 tonnes de déchets solides urbains contre 226,63 tonnes selon des estimations de recouvrement. Une quantité importante de matériaux recyclables a été trouvé à être produite à l'intérieur de la zone d'étude. Engagé des dépenses de carburants sur les seuls camions, faire dépasser le salaire mensuel de 400 collecteurs de déchets. Collecte de déchets solides urbains, la récupération et le recyclage sont des alternatives pour lutter contre la pauvreté et contribuent énormément à la réinsertion sociale des personnes marginalisées. Des recherches supplémentaires sont nécessaires sur l'équation de la production de déchets pour les estimations de la production de déchets dans les zones non bien planifiées.

Mots-clés: Les déchets solides municipaux, la production, la modélisation, la logique floue, la récupération, la réutilisation, le recyclage, l'économie

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INTRODUCTION

Waste management through recycling is not only about removing waste from the environment and returning it as new products or raw material, it is also a tool of social integration and economic well-being. As towns and cities around the world expand and population grows, so do volumes of waste produced increase and the challenges of solid waste change. One major issue dealt with on daily basis is the quantification, characterization and choice of treatment option of the municipal solid waste (MSW) stream. In Nigeria at present, the amount of MSW; which are predominantly synthetic, fabrics, scrap metals, glass and plastic, ceramic; is reaching proportions that are sources of major concern, on the streets, in and around the residential areas [1]. Municipal solid waste has received growing attention both on the local and international scenes [2-10].

This case study investigates municipal waste generation using a mathematical model; materials recovery potential, reuse and recycling using direct collection and qualitative separation method are examined. Comparison of the income of the collectors to the daily operational expenses of the trucks and other equipment are also investigated.

MATERIALS AND METHODS

Study area

The University of Maiduguri campus and the 202 and 303 housing estates in Maiduguri, in the north eastern part of Nigeria; constitute the study area enclosed in dotted area of Figure 1. Roads, streets, dumping bins and commercial activities are well paved and are easily accessible. The University of Maiduguri houses about 40,000 people; students, staff and business owners [11], while the 202 and 303 Housing Estates areas house a population estimates of 9, 000 people [12].

Data Collection

The various open dumps and bins were sectioned so as to have a better grasp of the study area. Three Diesel trucks, of 5 tonnes each, were involved in the waste collection according to specific routes. Three private local MSW collection companies' staff were involved and followed during their daily routines of waste collection and disposal.

These MSW collection outfits were: CONFER cleaners, MARION cleaners and MUSFAT cleaners. The monthly average staff wage was =N= 9,000.00 ($ 56.25) each [2].

Data Analysis

The fuzzy logic based model takes into consideration several parameters of waste production, such as population density, maximum building density, commercial traffic, area and type of shops, road network and its relative information (e.g. road width, dead-end streets, etc) linked with the allocation of waste bins. The model also follows a unified and correlated categorization approach for all commercial and industrial activities in the areas of study using a weighting system for all of the considered factors as shown in the following equation (1), used to calculate the final solid waste generation [13].

$$Total\ Waste = \sum_{i=1}^{m}\left(a_i x_i + \sum_{j=1}^{n} b_{ij} y_{ij}\right) \quad (1)$$

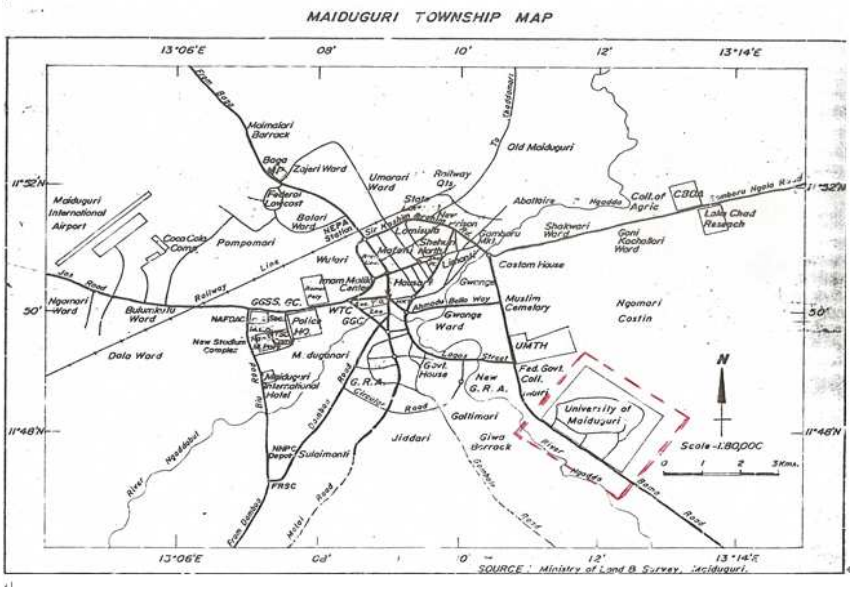
where a_i is the population of the examined area i, x_i is the value of the daily waste production per citizen in the area i. Also, b_{ij} *is* the total area (in m^2) of every commercial activity j in the particular segment area i, and y_{ij} is the coefficient related to waste generation of the commercial activity j in the area i. Furthermore, m is the distinct set of areas, used for the calculation of the total solid waste generation, while n is the total number of commercial activities in each predefined area.

The fuel consumption rate is estimated using the equation suggested by Thuy and Bruce [14]:

$$r_{H-Trl} = \frac{F_T - T_I \times r_I - (D_T - D_{H-Trl}) \times r_{Trl}}{D_{H-Trl}} \quad (2)$$

where $r_{H\text{-}Trl}$ is house -to- house -traveling fuel consumption rate (L km^{-1}); F_T is total daily fuel quantity (L); T_I is total idling time (hr); r_I is idling fuel consumption rate (L hr^{-1}); D_T is total traveling distance (km); $D_{H\text{-}Trl}$ is distance traveling within collection areas (km); and r_{Trl} is transportation –traveling fuel consumption rate (L km^{-1}). Note that the price of the fuel was taken as =N= 160.00($ 1.00) per liter.

Figure 1: This figure shows map depicting the study area delimited by the dotted lines in Maiduguri, Nigeria [15].



RESULTS

Figure 1: This figure a typical waste collection site and a truck used in waste collection

Table 1: This table shows types of materials present in MSW of the study area

Types of Materials	Percentage (%)
Sand/ inert materials	28.0
Food remnants	4.0
Grass/ leaves/shrubs	10.0
Metals(Cans/ tins)	9.5
Plastics	20.0
Bottles	11.0
Paper and Magazines	15.0
Ceramics	2.5

Using equation 1, the population data and average daily MSW production rate of 1.2 kg/ day/household [16], through which the total yearly waste in the study area was estimated to be 255 tonnes. The overall calculations in the subsequent sections were divided into daily and weekly collection, considering four weeks in a month. Annual analysis was achieved by multiplying the monthly results by 9, having in mind that the university closes for 3 months, during the long vacation; a period when recreational as well as commercial activities were very low if not inexistent.

Table 2: This table shows annual collection of recyclables

	Bottles (kg)	Rubber/Plastics(kg)	Metal scraps(kg)	Paper/Magazines(kg)
Daily collection	10	150		95
Monthly collection	300	4,500	6,200	2,850
Yearly collection	2,700	40,500	55,800	25,650

Table 3: This table shows fuel expenses on Waste collection trucks

	Fuel (Litres day^{-1})	Amount(=N=L^{-1})	Daily expenses (=N=)	monthly expenses(=N=)
Truck	30	160.00	4,800.00	134,400.00
Total				1,209,600.00

DISCUSSION

The fuzzy logic based mathematical model was able to predict 255 tonnes of MSW generated in the study area (i.e. 255 tonnes by the model against 226.63 by the actual collection). This is due to the well-structured nature of the study area and placement of refuse bins; which gives easy access to most MSW sites. However, the discrepancy can be attributed to the samplings as not all the MSW could be accounted for in the study. Another explanation for these figures may be that the recycling culture in the community is increasing; therefore, MSW with potential value were not discarded. They are re-used, kept for later collection, or exchanged with other incentives from government offices and community initiatives to pay for the recyclables. This goes a long way in the promotion and support of the 3Rs (Recover, Re-use and Recycle) campaigns.

Underlying economic development, household size, employment changes, as well as the impact of waste management practices are other factors that might influence solid waste generation interactively.

Countries which have long-term experience in waste management put social aspect at the top of the decision making process, while the beginners, countries which are

starting to implement waste source separation and recycling schemes often ignore this aspect [17]. Awareness, raising campaigns using messages such as Reduce – Reuse – Recycle, proper disposal can be used to change attitudes and modify behaviours amongst households and businesses.

Beverages in cans and plastics as well as other disposable means are mostly used in the university. This explains the high amount of plastics, paper and magazines but low food remnants as mainly snacks are consumed. The annual estimate of metal, mainly aluminum cans; obtained annually by the waste collectors; depicts truly the major activities of the population in the study area.

Comparison between the monthly fuel expenses on the trucks (Table 3) and waste collectors wages shows the economic benefits of involving more people in the MSW collection process, not to mention the financial benefits of recoverable and recyclables shown in Table 2. It could be observed that, on fueling alone, the wages of at least 400 waste collectors was used not to mention the polluting effect of these trucks which in most cases lack maintenance and are prone to breakdowns.

Waste management demands the adoption of new eco-political strategies clearly based upon a greater sense of environmental justice and foresight. The current refuse bins provided by the state government in the study area, are an example. Places which were once clean and MSW free are now being littered. Health-care services, traffic and transportation, education and cultural activities are the most challenging in solid waste management; but have been less frequently considered by most policy makers.

Interdisciplinary planning programmes are of crucial importance in order to identify policy instruments and strategic decisions that contribute to the development of sustainable waste management [18]. There is no single solution to the problem since the drivers behind MSW systems may vary significantly from city to city. In this context, the development of a common strategy to attain a sustainable management has been increasingly difficult. In this regard, Francisco et al. [19] who went further to suggest that waste -to- energy alternatives, strong waste reduction policies, a shift on waste composition and generation triggered by a demographic change, could be part of the scenario of the future.

Developing countries are poor and some of them badly governed. Waste management is a field of activity where supply cannot meet demand. There is need to involve more people in waste collection at the source, sorting of the MSW, before heading to the eventual treatment centres. Social perception of waste collection as a low class job should be casted away, as David [20] pointed out: a look back at relatively recent history can be cause for optimism. It was perhaps only 60 years when solid waste management practices in today's developed countries resembled what is common today in developing countries.

CONCLUSION

The study concludes as follows:

a. The study showed that the fuzzy logic based mathematical model can accurately predict the amount of MSW generated.
b. An important amount of reusable and recyclables could be obtained even though the study area was small but committed human effort of the collectors was high.
c. Expenses incurred in the course of fueling of the trucks alone, do exceed the monthly wages of 400 waste collectors. Engine oil and other maintenance operations or spare parts were not even included.
d. MSW collection, material recovery and recycling are alternatives ways to fight poverty, and can contribute immensely towards social re-insertion of marginalized people.
e. The waste production equation could be used to estimate the waste generation estimates in not well planned areas, in order to improve general waste management and planning.

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CONFLICT OF INTEREST

No conflict of interests was declared by authors.