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Waste Management Strategies in K-12 Schools in North Central Nigeria: An Appraisal in Jos

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Abstract: ***Waste management in educational institutions plays a critical role in fostering sustainable environmental practices and promoting public health. This study appraises waste management strategies in K-12 schools in Jos, the capital city of Plateau State, North Central Nigeria. Using a mixed-method approach involving surveys, interviews, and direct observations in both public and private schools, we assess the types of waste generated, current disposal practices, awareness levels, and institutional policies on environmental hygiene. The findings reveal significant gaps in infrastructure, policy implementation, and environmental education, with most schools lacking organized waste sorting and recycling systems. Recommendations are made to enhance sustainable waste practices through policy reform, teacher training, student-led green initiatives, and public-private partnerships.***

Keywords: fuzzy logic, sustainable waste practices, waste management

1. Introduction

Effective waste management is an essential component of a healthy learning environment and a sustainable society. In many low- and middle-income countries, school-based waste management is often overlooked despite its implications for public health, sanitation, and environmental education (UNICEF, 2019). K-12 schools, comprising pre-primary to senior secondary levels, generate various types of waste, including organic waste, plastics, paper, and hazardous materials like laboratory chemicals. If poorly managed, these wastes can pose risks to student health, contribute to environmental degradation, and diminish the overall quality of the learning experience.

Proper waste handling in schools not only improves hygiene and reduces disease transmission but also offers an opportunity to educate students about environmental stewardship from an early age. Children and adolescents are critical agents of change; when equipped with the right knowledge and skills, they can influence household and community behaviors on waste reduction, reuse, and recycling. Thus, schools serve as important platforms for instilling lifelong environmental values.

The global shift toward sustainable development, underscored by the United Nations Sustainable Development Goals (SDGs), particularly Goal 6 (Clean Water and Sanitation) and Goal 12 (Responsible Consumption and Production), calls for strengthened institutional capacity to manage resources and waste responsibly. Schools must align with these goals by ensuring safe, inclusive, and sustainable learning environments. Despite national policies promoting environmental sanitation in Nigeria, the implementation at the school level is often weak due to inadequate funding, limited technical know-how, and absence of monitoring frameworks (Olufemi et al., 2021).

Jos, the capital of Plateau State in North Central Nigeria, presents a unique context characterized by rapid urbanization, socio-economic diversity, and a growing student population. With these dynamics come challenges in public service delivery, including waste collection and disposal in educational institutions. Although both public and private schools contribute significantly to waste generation, their capacity to manage waste varies, often influenced by school size, location, and administrative commitment. This study aims to systematically appraise the waste management strategies in K-12 schools in Jos, identifying the strengths, challenges,

and opportunities for sustainable improvements. By highlighting gaps and good practices, this work contributes to evidence-based interventions for enhancing school sanitation and environmental education in Nigeria.

Underlying economic development, household size, employment changes, as well as the impact of waste management practices are factors that might influence Municipal Solid Waste MSW generation interactively (Moniruzzaman, Bari and Fukuhara, 2011). Countries with 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 (Sviatlana, Nils and Monika, 2010).

Awareness raising campaigns using messages such as the 3Rs: Reduce – Reuse – Recycle, proper disposal can be used to change attitudes and modify behaviors amongst the staff and students (Sviatlana et al, 2010; Dauda, Oumarou and Baba, 2012). Studies reveal a concentration of plastic and non-biodegradable drink packs in the schools and these constitute a large percentage of MSW (Oumarou, Dauda, Abdulrahim and Abubakar, 2012).

Lack of availability of the continuous data for generation, socio-economic and demographic variables makes it difficult to predict MSW generation for the developing countries like Nigeria (Ogwueleka and Ogwueleka, 2011). Conventional models fail to predict MSW generation for situations (Kolekar, India, .and Chakrabarty 2017). Moreover, uncertainties are involved with the collected data, hence it becomes exceptionally complicated to finalise the most suitable model for waste generation prediction (Moniruzzaman, Bari and Fukuhara, 2011). Fuzzy logic is a form of multivalued logic derived from fuzzy set theory (Oumarou, Dauda, Abdulrahim and Abubakar, 2012). With fuzzy logic, rules and membership functions can be used to approximate any continuous function to any degree of precision, dealing with the concept of uncertainty. Using reasoning that is approximate rather than precise (Ogwueleka and Ogwueleka, 2011).

Several studies have demonstrated the effectiveness of using fuzzy logic, for accurate estimation of urban solid waste for municipal solid waste generation modeling (Nikolaos and Alessandra, 2006; Ogwueleka and Ogwueleka, 2011; Oumarou, Dauda, Abdulrahim and Abubakar, 2012).

"Geo-polymer concrete, made from waste materials like fly ash and slag, significantly reduces CO2 emissions in construction. By substituting traditional cement with these materials, the environmental impact of concrete production is minimised. This approach not only addresses the growing demand for cement but also promotes the use of sustainable building materials. Similarly, schools can adopt waste-based materials in their infrastructure projects, contributing to both waste reduction and environmental sustainability" (Dodo, et al., 2024).

2. Methodology

The schools are situated in Rayfield, Jos South Local Government Area of Jos. Plateau State, North Central Nigeria. The school population currently stands at approximately 650 children in number. With staff strength of over 100 and the parents and visitors, the schools have total daily population of over 950 people.

Figure 1: Satellite Map depicting study area
Source: Google Earth (2024)

Data Collection

The study area was examined through field observation. Two MSW collection staff employed by the school were involved and monitored during their bi-weekly routines of waste collection and disposal. Direct observation of the cleaning staff and interaction with the facilities managers and resident architect were carried out.

Questionnaires administered to school administrators and facility managers. Focus group discussions (FGDs) with teachers and senior students was conducted and direct observations using a structured checklist assessing waste bins, collection frequency, sorting practices, and visible waste accumulation.

Data Analysis

The fuzzy logic-based model (Nikolaos and Alessandra, 2006) takes into consideration several parameters of waste production, such as

population density, maximum building density, and waste generating activities linked with the allocation of waste bins. The model also follows a unified and correlated categorization approach for all potentially waste generating activities in the areas of study using a weighting system for all of the considered factors as shown in the following equation to calculate the final solid waste generation.

Total waste $\sum_i^m = 1(a_i x_i + \sum_i^m = 1 b_{ij} y_{ij})$

Where

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

3. Results

Using the fuzzy logic equation the population data and average daily SW production rate of 1.2 kg/ day/household (Oumarou, Dauda, Abdulrahim and Abubakar, 2012), through which the total yearly waste in the study area was estimated to be 45 tonnes. The overall calculations in the subsequent sections were divided into bi-weekly collections. Annual analysis was achieved by multiplying the monthly results by 9, having in mind that the school closes for 3 months, (1 month in First term, 2 weeks in Second term and 1 month in Third Term since they rum a short 2-week summer term) during the holidays; waste generation is minimal if not inexistent.

Direct observation of the schools over 6 months was recorded in pictures and presented in Figures 2 to 17. The pictures reveal a practice of recycling construction, vegetable and plastic waste materials, so actual collection was significantly reduced, to 33.2 tonnes.

Figure 2: Composting of vegetative waste for manure

Figure 3: Compost is used during planting of greens. Note the new building's "new" corrugated zinc roof recycled from a building renovated owned by the schools

Figure 4: Nursery of pepper seedlings nourished with the compost pit

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Figure 5: plastic (PET) bottles and used water sachets are sorted to be recycled into interlocking tiles for walkways

Figure 6: Timber to be recycled within the school premises

Figure 7a: Timber in various forms obtained from
Figure 7b: old trees in the school premises or felled when they become dangerous

Figure 8: Timber recycled into a rabbit hutch for Agricultural Sciences Laboratory

Figure 9: old trees sawn into planks and logs for seating

Figure 10: Recycling yard for building materials

Figure 11: Different types of soil is bagged in the recycling for planting

Figure 12: Iron work in play areas created from recycled plumbing pipes after replacement with new PVC pipes

Figure 13: New basketball court fixtures made from new and recycled steel

Figure 14: "Stadium" seating made from recycled Materials

Figure 15: Garbage receptacles from recycled steel, water drums recycled for non-biodegradable waste

Figure 16: Tissue holder for curtain rings

Figure 17: Waste to art in preschool

Table 1: Solid Waste (SW) Materials present and recycled in the study

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Types of Materials	Percentage Available	Percentage Recycled	Remarks
Sand/ inert materials From construction and daily sweeping	5.0	90	Used in filling potholes on the internal untarred roads and backfill for ongoing construction works.
Food remnants from fruit/ lunch breaks of staff, students & security guards	4.0	100	Together with the grasses, leaves and shrubs are composted and used in the school gardens and farm.
Grass/ leaves/shrubs	15.0	100	Together with food remnants are composted and used in the school gardens and farm.
Metals (Cans/ tins) Building materials	2.5	100	Cans are collected and sold to local tinkers. Offcuts of other metals such as aluminium and steel are packaged and reused in the ongoing construction.
Plastics	25.0	98	Bottles are collected, washed sterilised and reused in the staff canteen for selling local drink. Bottles that cannot be used (missing caps or squeezed and packed for plastic recycling sites.
Glass	0.5	100	Glass bottles are collected and used for waste to art in the creative arts programmes.
Paper and Magazines	25.0	95	Papers that are used on one side are reused in the administrative units. Sensitive materials from finance are shredded and used as paper mâché in the school waste to art programmes, a small percentage is incinerated (3%).
Ceramics Tiles	1.5	97	These are kept and reused in paving some covered outdoor spaces. The rest are discarded to local landfills.
Timber	21.0	100	Timber from the trees is converted in planks, joist sand rafters for the ongoing construction. The rest is used for firewood
Outdated equipment	0.5	10	Perhaps the most difficult to recycle, a few such as computers and printers are used as teaching aids, the rest are discarded in landfill.
Total	**100**		

Table 2: Summary of collection of recyclables

Collection	Bottles (Kg)	Rubber/Plastics (Kg)	Metal Scraps (Kg)	Paper/Magazines (Kg)
Daily	0.5	3	0.03	6
Bi-weekly	7	42	0.4	84
Monthly	28	75	7.5	168
Yearly	182	1,092	90	2,016

4. Discussion

The fuzzy logic based mathematical model was able to predict 45 tonnes of SW generated in the study area (i.e. 45 tonnes by the model against 32.3 by the actual collection). This is due to the well-structured nature of the study area and placement of waste baskets in classes and designated outdoor areas. Collating was even made more predictable because the Greening principles used by the school management where each department has 3 bins, one for paper, one for plastics and one for noncombustible paper which is taken to landfills. However, the discrepancies can be attributed to the samples taken as not all the SW could be accounted for in the study. The Green principle employed by the community is showing an increase in the recycling culture; therefore, SW with potential value was not discarded. They are reused, kept for later collection. The continuous education of both the staff and students and even the construction workers who are instructed on careful dismantling of building materials goes a long way in the promotion and support of the 3Rs (Recover, Re-use and Recycle) campaigns.

5. Conclusion

The study concludes as follows:

The study showed that the fuzzy logic based mathematical model can accurately predict the amount of SW generated.

A significant quantity of reusable and recyclables could be obtained through the study area was small but committed human effort of the collectors was high.

SW collection, material recovery and recycling are alternatives ways to combat high energy costs in waste disposal, and can contribute immensely towards greening of schools and passive maintenance of facilities.

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.

6. Recommendations

I. Waste management demands the adoption of new eco-political strategies clearly based upon a greater sense of environmental justice and foresight.
II. Places which were once clean and SW free are now being littered so there is a need for governments and policy makers to deliberately provide for Health-care services, traffic and transportation, education and cultural activities are the most challenging in solid waste management;.
III. Interdisciplinary planning programmers are of crucial importance in order to identify policy instruments and strategic decisions that contribute to the development of sustainable waste management
IV. Waste -to- energy alternatives, strong waste reduction policies, a shift on waste composition and generation triggered by a demographic change, should form an important part of the waste management policy for schools in the future.
V. Machine learning models can be adopted in schools to evaluate sustainable materials for construction, promoting eco-friendly practices while minimizing environmental impact" (Chen et al., 2023).
VI. There is need to involve more people in waste collection at the source, sorting of the SW, before heading to the eventual treatment centres.
VII. Social perception of waste collection as a low-class unrealistic job should be cast away

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