Original Research Article

AN INTEGRATED APPROACH TO THE MANAGEMENT OF MUNICIPAL SOLID WASTE IN A TYPICAL CITY IN SOUTHWEST NIGERIA

ABSTRACT

A study of the prevailing management of municipal solid waste (MSW) in Ado Ekiti, a city in southwest Nigeria was undertaken using desk and field studies. The composition of the MSW derived from onsite waste sampling comprised plastics (28%), food (26%), paper/cardboard (14%), metal (7%), rubber (6%), textile (6%), glass (4%), leather (4%), fines less than 10mm (3%) and wood (2%). Analysis of the waste shows that the calorific value is greater than the required minimum value of 7MJ/kg required for the applicability of incineration. However, the criteria for a regular supply of refuse derived fuel (RDF) of at least 50,000 metric tons per year minimum value of 7MJ/kg required for the applicability of incineration required for incineration may not be met. An integrated MSW framework comprising reduction, reuse, recycling, recovery (composting), incorporation of the informal sector; public private partnership (PPP); public enlightenment and enforcement of regulatory laws on sanitation is proposed. Incineration of the MSW is not recommended due to its relatively expensive installation costs and inadequate supply of RDF. Active participation of PPP is vital to effective financing and thus implementation of the framework. A well engineered landfill is also proposed as none exists in Ado Ekiti.

Keywords: *integrated management; municipal solid waste; recycling; incineration, composting*

1. INTRODUCTION

The wealth acquired by global countries increased by 34% between 1995 and 2005 and has continued to increase thereby resulting in high rate of urbanisation [1]. Currently, approximately 50% of the world population lives in cities and it is projected that the population of the people that will live in the cities in 2050 will be the population of the world in 2000 [2]. No wonder the problems associated with urbanisation, such as increasing solid waste generation abound. The management of solid waste in urban areas has continued to be of great concern to the authorities of various countries in the world in recent years. This is not surprising as the management of solid waste is the most visible service rendered by the authorities in a town or city. Consequently, the visual rating of the quality of the management of solid waste is often used to judge the quality of other services being provided in the municipal. Ineffective management of solid waste will have adverse effect on the economy, environment and human health. Bad aesthetics will drive away visitors especially tourists that will contribute economically while non-collection and indiscriminate dumping of solid waste will block waterways, leading to flooding and pollution of the soil and water bodies, which may ultimately result in waterborne diseases such as diarrhoea, cholera, dengue and typhoid. This situation persists particularly in the developing countries such as Nigeria where existing infrastructure is incapable of dealing with the increasing volume of waste generated in urban areas. This situation has, however, provided employment opportunities for informal waste pickers who constitute approximately two million worldwide [2]

In Nigeria, the local government authority (LGA) is statutorily required to manage the solid waste produced in the municipality. The failure of the LGAs in this respect mandated various state governments to assume the role as the landscape aesthetics and health conditions especially in cities were becoming deplorable [3,4]. Data reported in the Annual Abstract of Statistics 2012 by the Nigerian Bureau of Statistics (NBS) showed that out of 28,197,085 households: solid waste was collected in 5,439,274 households; 2,716,037 households buried their solid waste, 5,615,273 households burnt their solid waste; 5,759,200 households disposed solid waste in public approved dumpsites; 7,965,527 households disposed solid waste in unapproved dumpsites while 701,774 households status on solid waste disposal in unknown in 2006 [5]. Similarly, a general household survey undertaken in southwest Nigeria by NBS in 2015 showed that: 28.8% of refuse generated was collected by the government agencies; 7.5% of refuse generated was privately collected; 1% of refuse generated was disposed in government bin or shed; 12.6% of refuse generated was disposed in household compounds; 17.3% was disposed in unauthorised refuse heap and means of disposal of 1.8% of refuse generated was unaccounted for [6]. The average waste generation per capita in Africa is approximately 0.65 kg/capita/day [2] while waste generation per capita in Nigeria ranged from 0.44 to 0.66

kg/capita/day [7]. It should be noted that there is no functional engineered landfill in Nigeria and therefore the solid waste collected by government agencies and formal private collectors is disposed of in open dumpsites.

Several authors have reported investigations on the management of solid waste in Nigeria. Majority have been undertaken using questionnaire administration and direct interviews to determine the characteristics of the solid waste generated and people's perception on the management of the solid waste [3,7-10]. Some of the investigations have been on the review of existing conditions of solid waste using reported data[11-15] In few cases, field data obtained from the chemical analysis of the leachate from refuse dumps have been reported [16-19]. Also, on-site collection of solid waste to determine the composition of waste produced by households have been undertaken by various researchers [20-22]. Some authors who have assessed the existing situation in Ado Ekiti have indicated general inadequacy of the system; without suggesting the framework for an integrated solid waste management [23-25].

There is no universally accepted method for the management of solid waste owing to variety in the composition of waste and the people's waste management ethics. However, the most common strategy is to prioritise waste management processes based on the highest level of waste reduction and material recovery in the waste stream, which is usually referred to as the hierarchy of integrated waste management [26-28]. The hierarchy has revolved from reduction, reduce and recycling, commonly known as 3Rs to reduction, reuse, recycling and recovery, commonly known as 4Rs. In recent times, holistic approaches such as the life cycle approach (LCA) that involve all the interconnecting factors influencing the management of solid waste have been proposed as the rigid use of the hierarchy method has limitations. Some of the limitations include: (i) the hierarchy method has no scientific basis, for instance, why recycling should be preferred to energy; (ii) the hierarchy method cannot assess the economic affordability of the solid waste systems; (iii) the hierarchy is not useful when a combination of options may be the optimal solution; (iv) the hierarchy method cannot account for variety of specific locations where the management of waste must operate effectively, such as small island and tourist destinations [29] Apart from LCA, another common method is the integrated sustainable (solid) waste management (ISWM) which has been built solely on elements in two triangles [30]. The first triangle which involves three key physical elements required for effectiveness and sustainability are: (i) public health that deals with good healthy conditions through effective waste collection; (ii) environment, which consists of environmental protection during all the waste management processes and (iii) resource management, which involves the use of the materials and its nutrients into beneficial use through recovery, reuse and recycling processes. The second triangle involves governance strategies for effective functioning of the system. It involves: (i) inclusiveness, which consists of the involvement of stakeholders; (ii) financial sustainability, which comprises cost effectiveness and affordability and (iii) sound institutions and pro-active policies [30]. Integrated sustainable waste management has also been reported to be an interaction between stakeholders that include everyone that has an interest or role; elements, which include technical aspects of solid waste management that needs to be considered simultaneously and aspects that encompass the regulatory, environmental and financial circumstances in the system where the solid waste management operates [31]. Obviously, a framework that encompasses all the aforementioned principles will result in an effective solid waste management system. It is worth noting that the principles are applicable in a waste management system that has a well-built infrastructure to support the required process, as it is often in the developed world. Unfortunately, the majority of the developing countries lack basic waste management infrastructure. It is therefore imperative to consider the existing conditions when applying established strategies to solve waste problems in the developing countries. In this study, an integrated MSW framework based on the prevailing conditions in Ado Ekiti has been formulated. It consists of principles of the contemporary hierarchy system, informal sector and public private partnership (PPP). With this, a pragmatic and effective management of the MSW produced in Ado Ekiti will be obtained.

2. METHODS

2.1 The Area of Study

The study area is Ado Ekiti, which is located in southwestern Nigeria and lies between latitude $7^{o}25'$ and $7^{o}47'$north of the equator, and between longitude $5^{o}5'$ and $5^{o}30'$ east of the Greenwich Meridian. It is the capital of Ekiti State, which is one of the 36 states in Nigeria that also has a federal capital territory with its capital located in Abuja. The population of Ado Ekiti in the last census conducted in 2006 was 313,690 (NPC, 2007) and the projected population of Ado Ekiti in 2017 is approximately 441,157.The solid waste generated in Ado Ekiti is managed by the Ekiti State Waste Management Authority (ESWMB). It is a department in the Ministry of Environment. The solid waste produced by the residents are collected from waste skips (dumpsters) that have a capacity of approximately $23m^3$

and are placed at market locations and at the end of main roads in the city. The solid wastes deposited in the skips are placed finally at open dumpsites located at Ilokun village, Federal Polytechnic Road and Ikere Road respectively. The skips at the market places are supposed to be offloaded daily while the others located along the roads are supposed to be offloaded within 2 days; however, frequent breakdown of trucks usually prevents regular offloading therefore resulting in overflow of the waste at various sites. The majority of the people that use the skips are traders, artisans and residents that live within the walking distance of the skips. Others include passer-bys and mainly well-educated residents that live far-away but have vehicles to transport their solid waste to the skip.

2.2 ~~The Study Procedure~~Methodology

The methodology ~~study procedure~~ involves the following steps: (a) collection of data; (b) analysis of data and (c) proposed integrated solid waste management framework. The collection of data ~~involved~~ included: (i) desk study, which involved obtaining the existing published work on the management of solid waste in Ado through the electronic media and hardcopy prints; (ii) reconnaissance survey, which involved a walk-over of Ado Ekiti to visually inspect its state of cleanliness; (iii) the administration of structured questionnaires and interviews, which were undertaken to obtain vital waste data that had not been obtained through the desk study and (iv) onsite collection of data to complement and as well validate waste data previously obtained. 125 questionnaires were distributed to residents in five main areas where waste skips provided by ESWMB are located. Furthermore, the composition of waste produced from high income, medium income and low income (also market) areas of Ado Ekiti was undertaken by collecting the waste produced from five households of each area over a period of one week. The households, which were randomly selected, were given 50-litre plastic bags daily to collect their solid waste. The average composition of the waste was then determined from the weights of various waste constituents. The pertinent waste data was analysed based on the existing sustainable development terms - physical, social and economic conditions of the study area. Finally, an integrated sustainable management of the solid waste was proposed.

Comment [B1]: Rationale for selection of respondents and total number of residents to be provided – it apperas to be starified random sampling. Am i right? then mention it

3. RESULTS

Statistics reported by [5] for Ekiti State showed that, out of 493, 739 households surveyed: 31,881 households have their solid waste collected; 26,488 households have their solid waste buried; 96,455 households have their solid waste disposed of at approved dumpsites; 198,887 households have their solid waste disposed of at unapproved dumpsites; 131,918 households have their waste disposed of through burning while 8,110 households method of disposal is unaccounted for in 2006 [5]. The distribution of regular households by method of solid waste disposal in Ekiti State in 2006 is shown in Figure 1. It could be seen that most of the solid waste produced by the residents are disposed inappropriately.

Comment [B2]: Is there any segregation at source , if no , mention it ; Is the MSW burnt ? then discuss the impacts on air quality and soil /water quality even with secondary data or published data

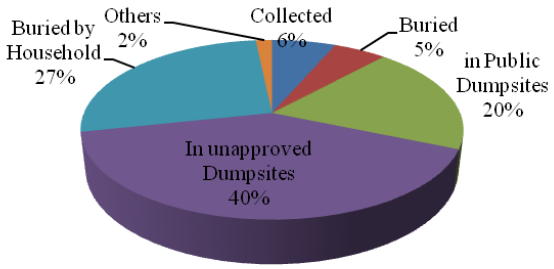

Figure 1: Distribution of Regular Households by Method of Solid Waste Disposal in Ekiti State in 2006 [5]

There are variations in the gender status of the respondents to the questionnaires in five main areas of Ado Ekiti; namely, Opopogboro, Ajilosun, Atikonkon, Oja Oba and Odo Ado shown in Figure 2. The average values of these are represented as Ado Ekiti. It could be seen that women constituted the highest respondents in Ado Ekiti. Similarly, the educational status of the respondents is shown in Figure 3. In general, all the respondents are literate. Residents with secondary education constituted the highest respondents, followed by those with primary education and technical education. Respondents with university education were the least. The method of storage of waste shown in Figure 4 indicates that majority of the waste was stored in waste bins, followed by storage in polythene bags and then buckets and basket in Ado Ekiti. The waste composition derived from the questionnaires is seen in

Figure 5. It could be seen that food waste constituted the highest proportion followed by wastes of paper/cardboard and plastics. In fact, there was a small variation in the percentages of food (32%), paper/cardboard (29%) and plastics (28%) respectively. There were also some quantities of metals (9%). The composition of waste derived from onsite waste collection is shown in Figure 6. In this actual data, it could be seen that plastics (28%) were the highest proportion of constituents in the solid waste generated in Ado Ekiti. Food (26%) and paper/cardboard followed respectively. Metal (7%), Textile (6%), Rubber (6%), glass (4%), leather (4%), Fines (3%) and wood (2%) followed respectively. It can be seen that there is similarity between waste composition derived from questionnaires and onsite waste composition obtained from various households. The trend is also comparable to the waste composition of solid waste in Ado Ekiti reported by [25] although there is variation in the proportions owing to the high content of leaves/vegetables in the latter.

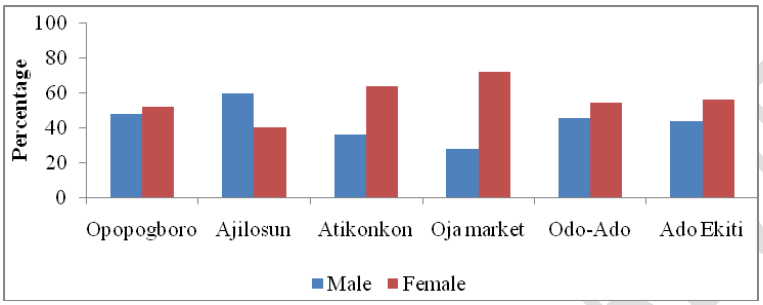

Figure 2: The gender status of the respondents

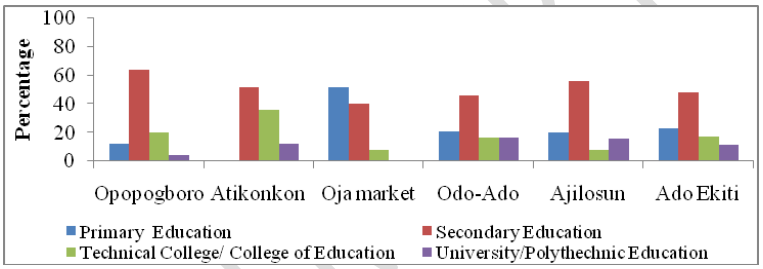

Figure 3: The educational status of the respondents

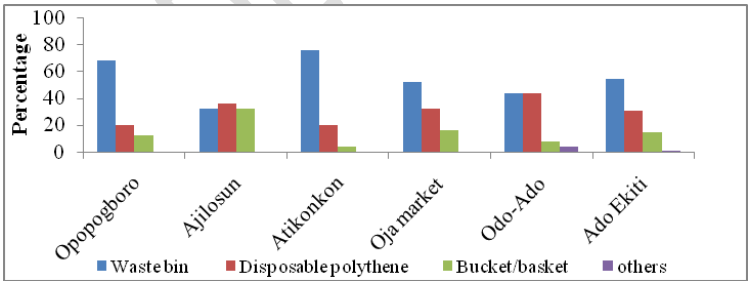

Figure 4: Method of waste storage

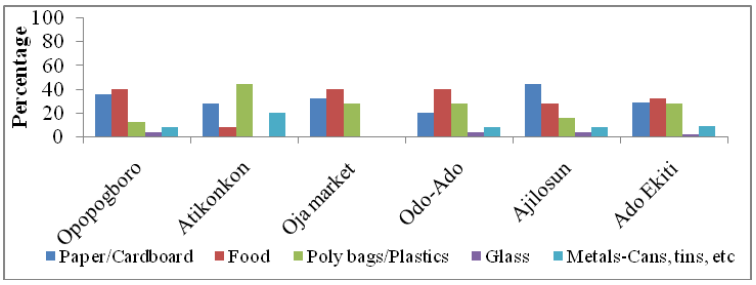

Figure 5: Waste composition derived from the respondents to questionnaires.

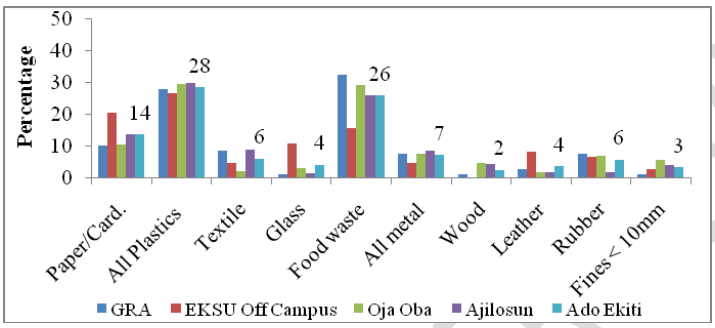

Figure 6: Waste composition derived from onsite waste collection

3.1 Proposed Integrated Municipal Solid Waste Framework

The proposed integrated approach in this study is a combination of the conventional hierarchy system and similar framework to that proposed by [31], but with more emphasis on sustainability owing to the peculiar conditions in Ado Ekiti - limited available financial funds and undeveloped solid waste management system. The data obtained from the current study had been utilised in order to achieve a pragmatic framework.

3.1.1 Framework Features:

(a) Application of strategy of the waste hierarchy system -reduction, reuse, recycling and recovery.

(i) Reduction and Reuse-this can be achieved through massive public enlightenment to inform the public of the prevailing problems of waste management and the need to buy only the essential goods. Enforcing the supermarkets and traders to charge for plastic (polyester) bags used for packaging goods. Encouraging manufacturers to make durable products, using minimum raw material. The waste producers should be encouraged to reuse products.

(ii) Recycling -It has been estimated that the basic start-up costs for a basic recycling programme may include the following [33]: Processing facility ($1500/month); Drop-offs ($1000 per unit); Equipment ($5000 – $10,000); Employees,-staff of five at minimum wage and cost of utilities. As the waste generation of cities similar to Ado Ekiti is approximately 0.5kg/capita/day [7], the annual waste generated in Ado Ekiti in 2017 would be approximately 80,511,153 kg (80,511 metric tons). The waste constituents that will be easily recycled at this initially stage will be paper/cardboard, plastics and metals thus a portion of the 40,256 metric ton recyclable waste will be transported to the recycling site annually. In Nigeria, a moderate permanent out- of-town processing facility can be built for about $15,000 and monthly wages of staff of five and cost of utilities will cost at least $2,000. Drop-offs will be done on the land on site. The land used for the operations will be ~~gotten~~ provided free of cost by the state government. Even with this, at least $20,000 will be required to kick-start the programme. Bearing in mind the population of Ado Ekiti, at least, a unit will be required for the three dumpsites.

(iii) Composting- Aerobic decomposition of the organic waste produced in markets, restaurants, sawmills and other similar sectors of Ado Ekiti in designated compost farms can produce high grade compost that may be used to improve the condition of soils used for agriculture and horticulture. The start-up cost will be significantly reduced as the land to be used for the aerobic digestion will be gotten free by the State Government. However, designated trucks, shovels, gloves, storage containers and quality packaging materials will also be will be required to operate efficiently. Farming is one of the main occupations in Ekiti State therefore the compost can easily be sold to farmers. It can also be sold to horticulturists in beautifying homes, institutions, public and industrial buildings, road shoulders and public parks.

(iv) Incineration-The following requirements are required for applicability of incineration [34]: (i) a matured and well functioning waste management system that has been in place for years; (ii) solid waste is disposed at engineered landfills; (iii) supply of refuse derived fuel is at least 50,000 metric tons per year; (iv) the lower calorific value must be at least 7MJ/kg and never below 6MJ/kg; (v) skilled staff can be employed;(vi) the community is willing to pay for treatment costs using incineration through management charges and disposal costs. In order to assess the viability of incineration for the MSW produced in Ado Ekiti, an evaluation of the energy content of MSW is required. Whereas many models have been reported in calculating the energy content of MSW, conventional ones are considered to obtain and estimate herein. A conventional way of calculating net calorific value (Hn) is reported by [35] as follows:

$$Hn = 88.2P_l + 40.5(G + P) - 6W \quad (1)$$

Where:
Hn = Net calorific value (kcal/kg).
P_l = Plastics, percent weight on dry basis.
G = Garbage, percent weight on dry basis.
P - Paper, percent weight on dry basis.
W = Water, percent weight on dry basis.

Similarly, [36] reported that energy content of solid waste can be calculated as follows:

$$E = 0.051\big(F + 3.6(CP)\big) + 0.352(PLR) \quad (2)$$

Where:
E = is the energy content of the waste in MJ/kg
F = is the fraction of Food/garbage in the waste (%)
CP= is the fraction of Cardboard and Paper in the waste (%)
PLR= is the fraction of Plastics in the waste (%)

Using equation (1), energy content of the MSW for Ado Ekiti shown in Figure 6 is approximately 4131.70kcal/kg, which is equivalent to approximately 17.30MJ/kg. Similarly, the energy content of the MSW shown in Figure 6 using equation 2 is 13.78MJ/kg. These values are greater than the minimum requirement of 7MJ/kg. Also approximately 80,511 metric tons of MSW yearly produced in Ado Ekiti exceeds the minimum requirement of 50,000 metric tons per year.

The cost of an incineration plant can be estimated using the following expression [37]

$$I = 2.3507 \times C^{0.7753} \quad (3)$$

Where:
I= is the investment cost in million dollars
C= is the plant capacity (1000 metric tons of waste/year)

An incineration plant for an annual estimate of 50,000 metric tons per of refused derived fuel (combustible MSW) RDF will cost approximately $48.80 million. This amount is not affordable for both the state and federal governments of Nigeria. In addition, annual 50,000 metric tons of RDF may not be obtainable from the MSW produced in Ado Ekiti as part of the RDF in the waste stream would have been recycled as this option is more economically. Therefore, the option of incinerating the MSW may not be feasible at this stage and is thus not included in the framework

(b) Public–Private Partnership

According to [38], Ekiti State received $8 million in September, 2017 from the federal government, the third lowest paid state of the 37 states of Nigeria. Ekiti State depends solely on the monthly financial fund allocated to it by federal government for payment of salaries and execution of essential projects. In recent times, relatively low price of crude oil, which is the major source of revenue for Nigeria, has caused a dwindling economy resulting in financial constraint in all the states of the federation. It is thus obvious that the government of Ekiti State may not be able to execute the processes of the hierarchy system –recycling and composting, earlier highlighted. It is therefore imperative for the government of Ekiti State to seek a realistic alternative means of successfully financing and executing an effective MSW management system. A public-private partnership (PPP) is urgently needed for effective management of the MSW produced in Ado Ekiti. Wealthy green entrepreneurs should be sought for financing and execution of the pertinent projects. Successful implementation of PPP will make the management of the prescribed projects affordable to Ekiti State government; socially acceptable to residents and thus achieving a sustainable healthy environment. In addition, it will provide the necessary technical expertise required to build and manage an effective MSW framework in Ado Ekiti and other major towns in the state. The funding will provide adequate facilities for the collection, recycling, recovery.

(c) Effective Public Enlightenment and Enforcement of Regulatory Laws on Sanitation

Massive public enlightenment of the residents of Ado Ekiti on sustainable MSW management is required. This will educate the residents of the negative consequences of bad sanitation on health and ability to make wealth out of the waste generated though the implementation of the 4Rs. This could be achieved though hardcopy prints, and electronic and social media. Adequate education will enhance the implementation of the regulatory laws on environmental protection in the state.

(d) Formalise Participation of Informal Sector in Recycling

Currently, few formal (registered) private companies engage in the collection and disposal of MSW. However, only the informal sector does the recycling of the MSW produced in Ado Ekiti. The informal sector comprises of a network of individuals that collect recyclable materials from residents and waste dumps. The informal sector is not regulated and appears to practise under unwholesome conditions. Regulation of the sector will enhance the collection of accurate data on recycling rates, which is required in effective planning of the framework. It is imperative to incorporate this sector with the existing formal sector to improve the waste management in the city. Furthermore, it will provide fair trade in the scrap business.

(e) Construction of a Landfill

Although, landfill is the least desired option in the management of MSW, an appropriate engineered repository is required for final disposal of the remnants of MSW from the processes of 4Rs as there is currently no landfill in Ekiti State. If the 4Rs processes are put in place, one moderately large landfill will be suitable initially.

4. CONCLUSION

A study on the current state of management of MSW in a typical city in Ssouthwest Nigeria has been undertaken. In order to achieve a pragmatic result, the prevailing data obtained from the current study has been used in formulating an integrated MSW framework for Ado Ekiti. The framework comprises among others, the contemporary hierarchy system-reduction, reuse, recycling and recovery of MSW, which minimises the final waste being dumped into the landfill. The framework also incorporates the formal and the informal private sectors and public enlightenment and enforcement of regulatory laws on sanitation. Finally, private partnership public (PPP) is incorporated to ensure adequate financing of all the components of the framework. Recovery only via composting is recommended as incineration of the MSW is not feasible under the prevailing conditions. Although the requirement of a minimum value of 7MJ/kg for the applicability of incineration is fulfilled, a consistent supply of at least 50,000 metric tons per year RDF is not guaranteed thus making incineration a non-viable option. This is further supported with relatively

Comment [B3]:

Comment [B4R3]: Quote if there is any other sucesful PPP model either in Nigeria and eleswhere and discuss what lessons can be learnt for your study area

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high installation cost of an incinerator, which is unaffordable for the state government. Provision of an engineered landfill is also one of the components of the proposed framework.

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