Developing A Sustainable Solid Waste Management Strategy For Nigerian Urban Centers

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Abstract- Solid waste generation and management in Nigerian urban centers is a replica of what is obtained in most cities of Africa and other cities of developing countries. It is characterized by improper collection; transportation and disposal coupled with lack of data to facilitate in planning for sustainability. These problems therefore, informed the need to develop a strategy for sustainable solid waste management. This is in tandem with global initiatives which greatly support the prioritizing of solid waste management as an important facet of sustainable development. This study conceptualized solid waste management system components of generation, handling and disposal for a sustainable solid waste service delivery in Nigerian cities.

Index Terms- Solid Waste Management, Sustainable Development, Urban Centers

I. INTRODUCTION

Out of the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development, adopted by the 193 UN Member States in September 2015, at least 12 SDGs and their pertinent targets have a direct link to solid waste management In essence, the SDGs have the same driving forces as those that have been driving development of SWM activities over time, namely: public health, environmental concerns, and resource value, with relatively recent additions of climate change and inclusivity (Wilson, 2007, Rodic & Wilson, 2017).

As a key utility service that more than 2 billion people are currently lacking, solid waste management (SWM) is a crosscutting issue that affects and impacts various areas of sustainable development in each of the three sustainability domains: ecology, economy, and society. The affected areas include living conditions, sanitation, public health, marine and terrestrial ecosystems, access to decent jobs, as well as the sustainable use of natural resources. Emphasizing this issue, the United Nations recognizes World Habitat Day 2018 with calls for increasing imagination and innovation to address global waste management challenges. According to the UN Human settlements Programme (UN Habitat), 99 percent of purchased items are discarded within six months and the world produces two billion tonnes of waste annually.

The SDGs, the Paris Agreement on climate change and the New Urban Agenda (NUA), all address solid waste management. Also, since 2000, the World Bank has committed over $4.7 billion to >340 solid waste management programs in all six regions of World Bank engagement. (Cleary, 2009, Guerrero et al., 2013, Navabi-Pelesaraei et al., 2017, Rodic and Wilson, 2017, Sharholy et al., 2008, Zhang et al., 2010, Pujara et al., 2019. Therefore improving solid waste management is the main goal of the UNDP-UNEP and Poverty Environment and Initiative (PEI).

Table 1. Relationship between Sustainable Development Goals and Solid Waste Management.

Driver		Sustainable Development		Solid Waste Management (SWM)
		Sustainable Development Goal (SDG) [i]	Specific Target	SWM Related 'Virtual SDG' [ii]
Protection of public health		SDG 11: Sustainable cities	11.1 Ensure access for all to adequate, safe, and affordable basic services; upgrading slums	→ **Goal 1. Ensure access for all to adequate, safe, and affordable solid waste collection services.** *Uncollected waste is often dumped in waterways or burned in the open air, thus directly causing pollution and contamination. Waste also clogs the drains, which exacerbates floods, keeping stagnant water and contributing to water-borne diseases and malaria. Children are among the most vulnerable, so they are affected the most.*
		SDG 3: Good health and well-being	3.2 End preventable deaths of children under 5 years 3.3 End malaria and combat water-borne diseases 3.9 Reduce illnesses from hazardous chemicals and air, water and soil pollution, and contamination	
		SDG 11: Sustainable cities	11.6 Reduce the adverse environmental impact of cities; special attention to waste management	
Protection of the environment	LOCAL	SDG 12: Responsible consumption and production	12.4 Environmentally sound management of chemicals and all wastes in order to minimize their adverse impacts on human health and the environment	→ **Goal 2. Eliminate uncontrolled dumping and open burning**, *as the first stepping-stone to achieving environmentally sound SWM practices.* → **Goal 3. Achieve environmentally sound management of all wastes, particularly hazardous wastes** (*either chemical or biological hazardous wastes*).
	LOCAL	SDG 6: Clean water and sanitation	6.3 Improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous materials	
	LOCAL	SDG 15: Life on land	15.1 Ensure the conservation of terrestrial and inland freshwater ecosystems and their services	
	GLOBAL	SDG 7: Affordable and clean energy	7.2 Increase the share of renewable energy in the global energy mix	→ **Goal 3.** *SWM technologies can derive renewable energy from (organic) waste.*
	GLOBAL	SDG 13: Climate action	SDG 13: Take urgent action to combat climate change and its impacts	→ **Goal 3.** *Adequate SWM practices can prevent emissions of large amounts of greenhouse gases.* [iii]
	GLOBAL	SDG 14: Life below water	14.1 Prevent marine pollution of all kinds, in particular from land-based activities, including marine debris	→ **Goal 1 and Goal 2.** *Extending waste collection to all and eliminating uncontrolled dumping will prevent waste (particularly plastics) ending up in the oceans.*
Resource value		SDG 12: Responsible consumption and production	12.5 Reduce waste through prevention, reduction, recycling, and reuse 12.3 Halve global food waste and reduce food losses along production and supply chains This SDG also contributes to SDG 2: Zero hunger – End hunger, achieve food security and improved nutrition, and promote sustainable agriculture	→ **Goal 4. Substantially reduce waste generation through prevention and the 3Rs (reduce, reuse, recycle) and thereby create 'green' jobs** *Waste prevention is the highest-ranking option in the waste management hierarchy. It is followed by reuse of products or their parts, and then by recycling of component materials.* → **Goal 5. Halve per capita global food waste at the retail and consumer levels and reduce food losses in the supply chain.** [iv]
Supplementary driver: Inclusivity		SDG 1: No poverty	1.4 Ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources and financial services, including microfinance	→ **Goal 4** *Reuse and recycling have a significant potential for creation of jobs.* → **Goal 1 and Goal 4** *In developing countries, SWM services are often provided by individuals and small and microenterprises. Any measures applied to support them will improve livelihoods and directly contribute to SDGs 1 and 8.*
		SDG 8: Decent work and economic growth	SDG 8: Promote inclusive and sustainable economic growth, employment and decent work for all	

Source: Rodic & Wilson, 2017

Municipal solid waste management (MSWM) refers to the collection, transfer, treatment, recycling, resource recovery and disposal of solid waste in urban areas). MSWM is an important facet of sustainable development for any country and global initiatives greatly support the prioritizing of SWM (Ndum, 2013). Municipal solid waste systems are essential component of the environmental infrastructure in human settlement. This system comprises all the activities undertaken from the point of waste generation up to the final disposal. It is an important environmental health service and an integral part of basic urban services However, Residential households are mainly the major stakeholders interested in receiving effective and dependable waste collection service at a reasonably low price. In most urban centers of developing countries, residential areas, mostly the low income residential areas, solid waste service are unsatisfactory. Residents normally give priority to water, waste water and electricity supply as these services are channeled through pipes.

Solid waste is generated and discarded according to public wants. These compounded the problems for the urban authorities and policy makers. Increased in generation and disposal of household solid waste became an increasing problems in urban areas due to high population density and urbanization; Household wastes are growing environmental problem in urban centers in both developed and developing countries around the world (Barr. *et al.*, 2001), as a result domestic solid waste poses a complex challenge for environmental policy (Barr, 2007) consequently, pressure to improve solid waste collection service arises as other service became available and awareness mounts regarding the environmental and health impacts of poor waste collection service. In cities of the developing world, municipalities are mostly responsible for the solid waste management at city level (Zurbrugg, 2012; Muggaga, 2006 & Cointreau, 1994). Various

actors or stakeholders participate in every solid waste management system in both the developed and the developing countries. In principle, these actors are part of every solid waste management; the municipal government NGOs/CBOs, households or service users, private formal/informal sectors and donor agencies. (Muller & Hoffman, 2001). However, in most Nigerian urban centers, municipal solid waste management is characterized by inadequate collection and improper disposal, due to the inability of the municipalities to handle the increasing quantities of solid waste generated. The uncollected waste littered the streets, roads and public drains and is an obvious cause of degradation of the environment.

Domestic solid waste management has been defined to encompass the full range of management activities for domestic waste streams from the point of generating the waste to the point of disposal (Cointreau *et al.*, 1984; Baud & Shenk, 1994 & Jones, 1995). Also (Bovea *et al.*, 2010 & Zurbrugg *et al.*, 2012, Cherian & Jacob 2012), highlighted that waste management is a complex process that requires a lot of information from various sources such as factors on waste generation and waste quantity forecast. However, these are generally unknown to government officials especially the responsible agencies

According to (Napoleon *et al.*, 2011 & Ukpong and Udopia, 2011) there is a general paucity of data on key waste variables such as generation rates, composition, densities, storage and transport. The United Nations Environment Program (UNEP, 2013), stated that in developing countries, data on waste generation and composition are largely unreliable and insufficient, seldom capturing system loses or informal activities. (chu *et al.*, 2011, UN-HABITAT, 2010). Without proper data it might be difficult to design sound strategies or to make wise budget decisions on waste management (Wilson *et al.*, 2012). Also, Cherdsatirkul (2012) stated that it is hard for government of developing nations to deal with MSWM issues because of lack of information and adequate data collection. In most Nigerian urban centers, reliable data on solid waste generation and composition is generally scarce and incomplete.

1.1 Integrated Solid Waste Management (ISWM)

The ISWM concept was established by the US environmental protection agency (EPA) in the early 1990s to expand existing solid waste management problems that aims to avoid many of the holistic approach to tackling solid waste management problems that aims to avoid many of the failing of previous technology driven approaches (Van De Klundert and Anshutz, 2001) Instead of focusing only on the disposal of solid waste, ISWM includes preventing waste, minimizing the initial generation of materials through being sent to landfills or incineration. Tchobanoglous *et al.* (1993), Benzaid *et al.* (2011), defined ISWM as selection and application of suitable techniques, technologies and management for the programs to achieve specific waste management goals and objectives. Bagchi (2004), stated that the goal of sustainable solid waste management is the recovery of more valuable products from waste with the use of less energy and more positive environmental impact. These according to the (EPA) comprise of hierarchy of activities; source reduction, recycling, waste combustion and land filling. The hierarchy is a useful conceptual tool for goal setting and planning at the national level, states and municipalities. The concept of ISWM discussed by Van De Klundert and Anschtz recognizes three important dimensions in waste management.

The Stakeholders involved in waste management, The (Practical and Technical) element of the waste system and The Sustainability aspects of the local context that should be taken into account when assessing and planning a waste management should be appropriate to local conditions and be feasible from the technical, environmental system. The important principle of ISWM is that a waste management, social, economic, financial, institutional and political perspective (Anschutz et al,, 2004), ISWM differs from conventional approaches and towards waste management by seeking stakeholder participation, covering waste prevention and resource recovery, and promoting an integration of different habitat scales (city, neighborhood, household) . In most developing countries authorities' efforts are more concentrated on waste collection and transport and open dumping.

Therefore, there is the need to develop more sustainable ways and means in turning waste into resources, reducing environmental impact of waste disposal, create employment opportunities improve health and environmental qualities. The objectives of ISWM is to deal with society`s waste in an environmentally and economically sustainable. ISWM can be used as an analytical tool for the analysis and assessment of the whole project cycle, especially for design, formulation, for monitoring and evaluation of a waste management project.

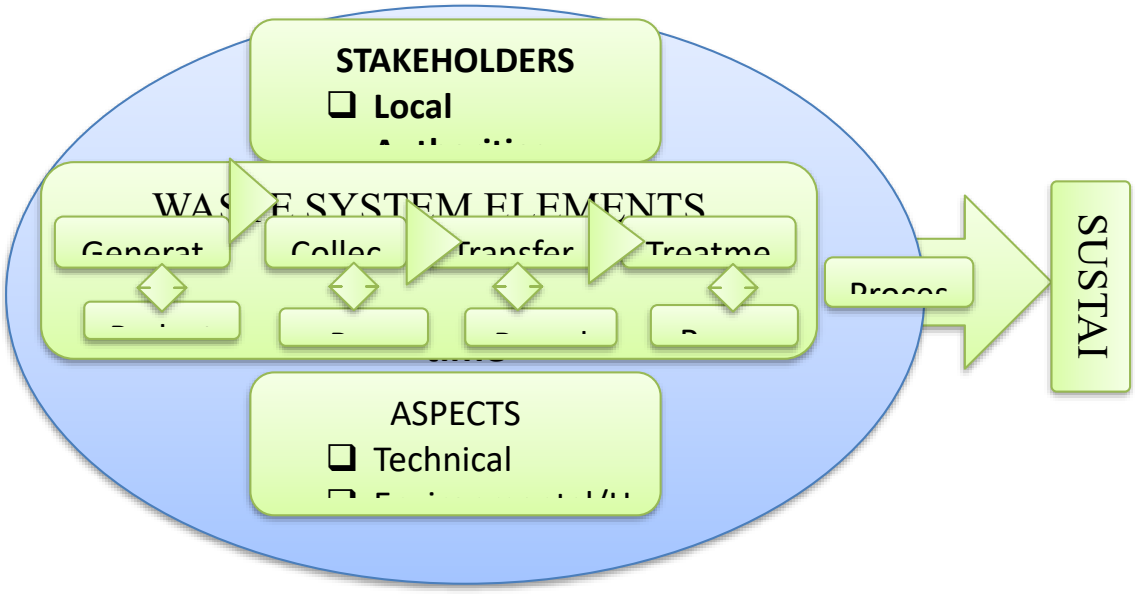


Fig 1: Integrated Sustainable Waste Management (ISWM) approach or model.

Source: Van De Klundert and Anschtz, 2005

1.2 The Modernized Mixtures Approach (MMA).

The modernized mixtures approach MMA is an integrated approach to (water and solid waste) infrastructure development, which is in particular relevant for situations of poor developed infrastructures and poor people. MMA is an approach which deviates both from the well-known western large scale high technological grid base as well as from familiar small scale, low-tech, decentralized and stand-alone technologies applied in many African communities.MMA approach refers to the development of medium and large scale environmental infrastructural systems which 'build upon' and are constructed from decentralized and centralized units which take into account of specific local conditions of developing countries.MMA integrates (Eco) technological, economic and social dimensions of environmental infrastructures (Spaargaren, 2005).

The approach is made up of three criteria of Accessibility, Flexibility and Sustainability. The approaches should be ecologically and institutionally sustainable, accessible (particularly for the poor), and institutionally and technically flexible, resilient and robust (Spaargeren, 2005). MMA has principles of mixed scales strategies, technological payment systems and decision making. It is referred to as "mixtures" because it takes the best features out of both (modern) decartelized and centralized systems and combs them into hybrid solutions which better fit the local situation of African cities. (Spaargaren et. al, 2005).

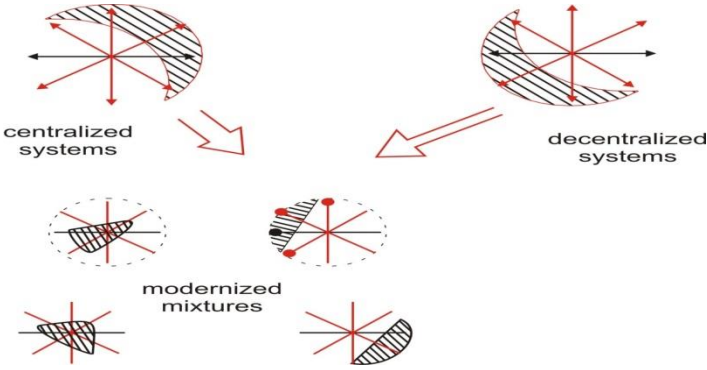


Fig 2: Modernized Mixtures Approach (MMA) (Spaargaren et al,, 2005)

Source: Solomon 2011

When compared to integrated sustainable waste management (ISWM) model, the MMA is similar as it also opts for an integrated approach too, including chains, combining multiple scales in organization, management and governance, and requiring the inclusion of technical as well as social scientific knowledge. The object of the MMA is to create a 'fit' between different infrastructural options on the one hand and the prevailing socio-economic, ecological, technological, and political conditions on the other. The conceptual framework basically consists of four (5) main parts, viz**:**

a. **The upper part**: the upper left part depicts the position of the household in the solid waste management chain

b. **Part II**: the second part shows three basic roles of households and their functions in the solid waste management chain: Households as solid waste generators, Households as handlers of solid of solid wastes in the primary phase of the chain and

Households as recipient of solid waste management services.

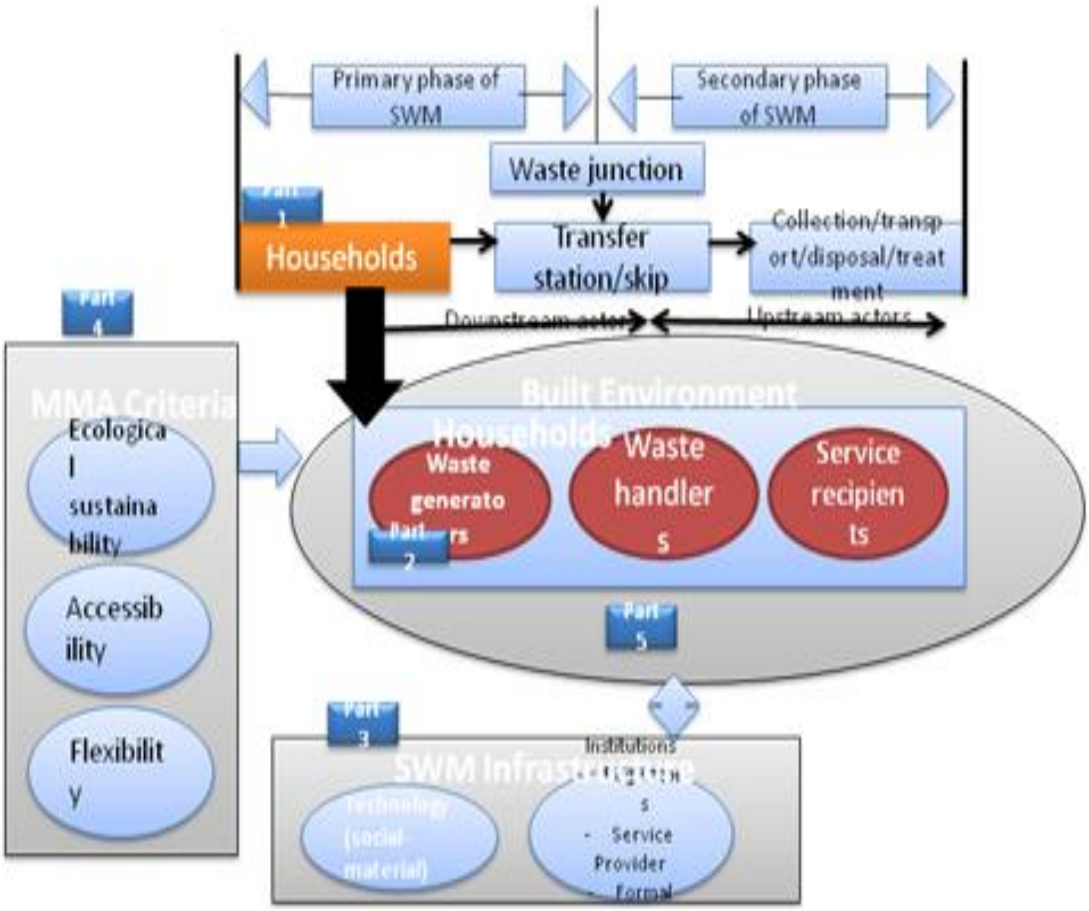


Fig 3: Conceptual framework for analyzing the role of households in SWM
Source: Solomon, 2011

c. **Part III**: this shows the solid waste management infrastructure which includes; The (Socio) technological infrastructure- that is materials as well as social elements The institutions, which can be divided into the official service regulators and the actual service providers. The actual service provider in this context includes formal and informal stakeholders

d. Part **IV**: this part of the framework represents the criteria relevant for the assessment of (new) socio-technical infrastructures to be developed with the used of the MMA.

e. **Part V:** The architecture/planning of the households. The built environment in this research refers to the local factors like architecture and infrastructure are major determining factors in solid waste management. For example, dwelling with courtyards may have space for storing waste for several days, but compact housing with no space for storage may necessitate that some waste is taken outside the property as soon as it is generated.

II. METHODOLOGY

Qualitative methods used in this study include: Reconnaissance survey, semi structured interviews and, direct observations). Information was obtained from the level of federal government represented by the official of National Environmental Standard Regulation and Enforcement Agency (NESREA), from officials of Bauchi State Environmental Protection Agency (BASEPA) Bauchi State Commission for Women and Youth Development and rehabilitation and the household level. Document reviewed include but not limited to; NESREA Act, 2007, environmental impact assessment Act of 1992, national environmental (sanitation and waste control) regulations, 2009, the management of solid and hazardous wastes regulations.

Quantitative method used was the household survey questionnaire and waste characterization study. When it comes to making appropriate decision in relation to the waste management of Urban Solid Waste (USW), which include Residential Solid Waste (RSW), two factors are important; The total volume and composition. Both these factors change with time and socio economic conditions (Singh *et al.*, 2011, Cherian & Jacob, 2012). Data were collected from a total of 378 households purposely

selected within the districts of Bauchi metropolis. Characterization study was carried out to determine the per capita daily waste generation and the percentage fractions of household waste constituents. Various statistical test procedures including means, standard deviation, and frequencies, Statistic Package for Social Science (SPSS), Spearman's correlation and regression analysis were the methods used to analyze the quantitative data from the study.

III. RESULTS AND DISCUSSION

3.1 Solid Waste Generation and Composition:

The conceptual framework used in this study for investigation of households' solid waste management is inspired by the theory of modernized mixtures approach (MMA), an expanded version of Integrated Sustainable Solid Waste Management (ISWM) which makes it possible the study of solid waste management practices from the perspective of households and conceptual framework developed by Solomon. This study found that per capita waste generation in the selected sample varies from 0.22kg/capita/day to about 0.48kg/capita/day; while 0.30kg/capita/day was obtained for Bauchi Metropolis. Similar studies compiled by Ogwueleka (2009) and (Adewumi et al, 2005), for major Nigerian commercial and urban centers showed the value of per capita solid waste generation ranges between 0.43kg/capita/day in Ilorin, Kwara state to 0.63kg/capita/day in Lagos as shown in Table 1.

3.2 Waste Composition:

Study found that domestic wastes constitute 61% organic (biodegradable, kitchen waste). This is typical of most wastes from cities of the developing countries. Other waste percentage fractions of each constituent of wastes generated in Bauchi metropolis is: Residues = 14%, Polythene = 13%, Paper = 4.2%, Glass = 1.9%, Plastics = 2.8%, Metal = 0.9%, Textiles = 2.2%.

Table 1: Comparative values of per capita waste generation for some Nigerian Urban Centers compiled by All Sites Engineering (2009), Sridhar and Adeoye (2003), Usman (2016)

City	Kg/capita/day
Lagos	0.63
Kano	0.56
Ibadan	0.51/0.219
Kaduna	0.58
Port Harcourt	0.60
Makurdi	0.48/0.54
Onitsha	0.53
Nsukka	0.44
Abuja	0.66
Abeokuta	0.60
Ado ekiti	0.71
Akure	0.54
Ile-ife	0.46
Ilorin	0.43
Bauchi	0.30

Other studies have indicated similar results. Stanley *et al.,* (2012) 87 % organic fraction in Sabon Gari Zaria, Ogbonna & Umunakwe (2015), 67 % organic fraction in Awka; (Stanley *et al.,* 2012), 61 % organic fraction in Samaru, Zaria and (Benjamin *et al.,* 2014) 56 % organic fractions in Abuja FCT, while Agbesola (2013) obtained 55 % organic fractions for Lagos Metropolis. Nabegu (2010), obtained 47% organic fraction in Kano, Nigeria. This result can justify the linkage of waste composition and economic activities at household level.

The nature of the food waste being organic suggests the possibility of recycling through composting. Therefore the implication is that, there is the need to regularly and efficiently evacuate waste in the study area, to avoid foul small, lecheat and methane production which are detriment to the health of the inhabitants.

The information obtained from the results of this study is vital in planning solid waste management at household level. It helps in identifying material categories and their relative proportions in the household waste stream for; potential source recovery reduction composting possibilities, and recycling. Also, full knowledge of the constituents and composition of the waste stream provides information which is essential in selection of the type of container most appropriate for storage and transport, choice of a suitable disposal method and determination of the environmental impacts of the waste if improperly managed.
Another importance of waste composition studies is when modeling waste management systems; waste composition is one of the most important parameters (Damagaard, 2010).

3.3 Waste Separation, Resources Recovery/Re-use and Recycle.

The current waste management practices applied by the households in Bauchi metropolis showed that the practice of waste separation at source is very rare as only 20 % of the respondents indicate that they practiced waste segregation at source. In most Nigerian urban centers, waste sorting or separation at source is not a common practice. Odewumi (2013), reported that there is very little attempt at sorting solid waste and the aspect has not received any attention in the waste management strategy in Lagos. (Adekunle *et al.,* 2011) reported that it is not a practice to separate waste materials at source or any point during its management in Nigeria.

The result of this study showed that households retain some of the items that they do not treat as waste. It was found that recovered materials such as plastics mostly in form of empty water and oil containers amount to 75 %, while metals such as empty milk and beverage containers amounted to 13 % and bottles 3 %. These materials or recyclables which are not treated as waste 32 % of the respondents indicates that they re-use these recyclables, 43 % give them to others as who might need it. But 12 % sell their own to waste vendors and 13 % mixed them with other wastes. the implications of the few percentage of the respondents that practiced waste sorting at source by obtaining recyclables exhibits the phenomenon of resource recovery in waste management.

3.4 Perceptions and Evaluation of Solid Waste Service Recipients in the Study Area

Households perceptions with regard to the need for transfer station or communal bin in their neighborhood is an important

factor in assessment of household solid waste service delivery as it integrates the downstream actors (Households) and the upstream actors (formal and informal stakeholders in providing solid waste services) Stationary wheel-containers (roro), masonry bins (designated dumping site), open space (open dumps) public drains and road junctions served as transfer stations in the study area. 64.5 % of the respondents indicated that they knew the importance of the communal bin in their neighbourhood in effective solid waste management and are willing to have it despite all other negative attributes associated with it, like bad odour and health implications.

While 17.5 % indicated that communal bin or transfer stations produced unpleasant smells and for that reason are not to be welcomed in their neighborhood. With regard to these opinion, similar observations was made by Odewumi (2013), where he reported that "Aatan" or transfer stations are not welcome by some residence due to the popular belief that it is the food basket of pets, like chicken, dogs, pigs and so on. The implication of households perceptions towards the location of the transfer station is that, their perceptions and opinions should influence the decision making process about the location of transfer station. Essentially the decision on the location of transfer station should take in to consideration the extent of resistance by households against the location of the transfer station in their neighborhood in addition to the factors such as health impact and accessibility (Solomon 2011).

Achieving sustainable development goals with respect to SWM in urban areas required a strategy built on the flow of urban waste (solid waste management chain) based on accurate and reliable information on the waste and its generators, (the households) and which identifies specific urban setting. The strategy should enhance waste management from the technological, socio-economic and environmental perspectives

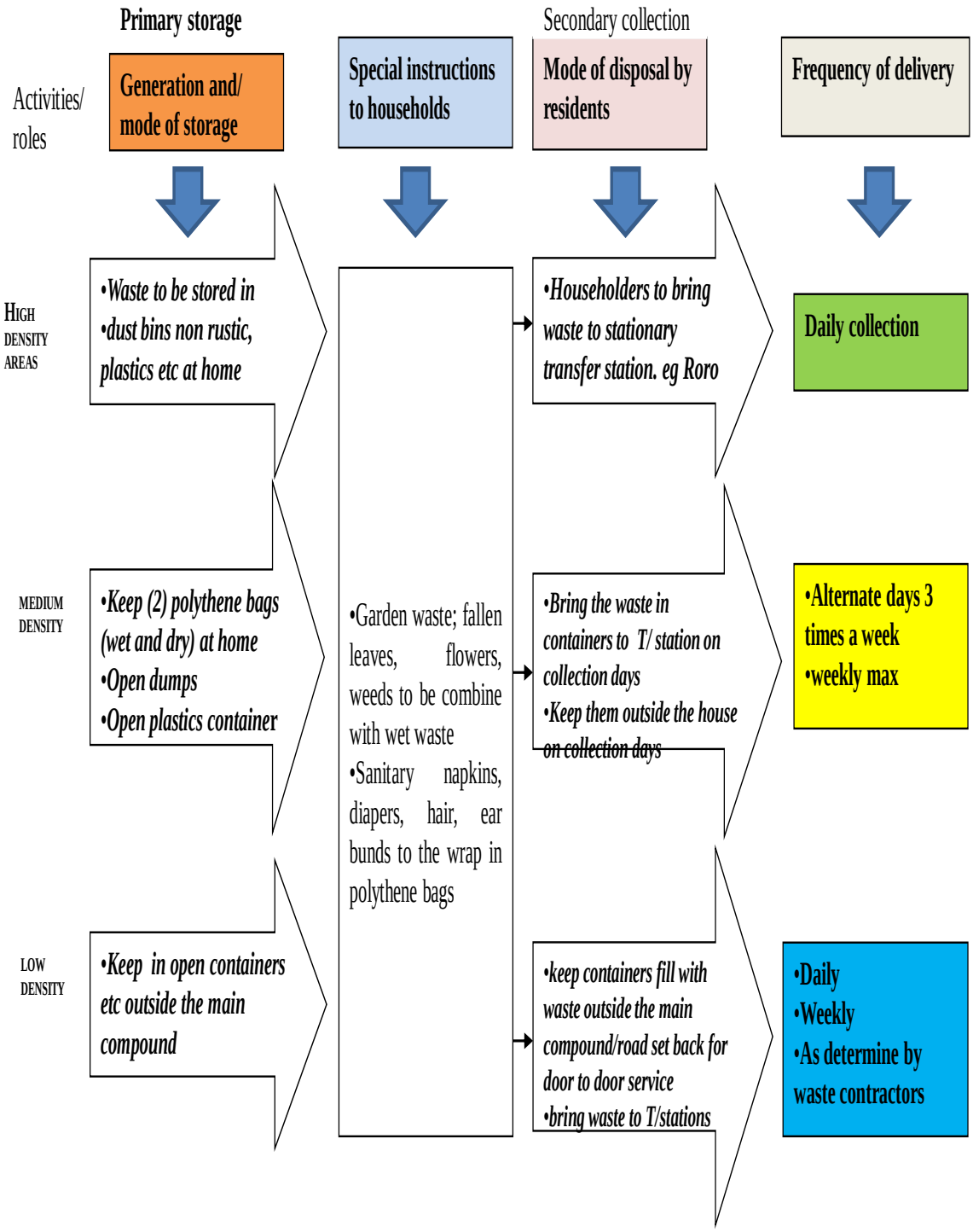
3.5 Domestic Solid Waste Management Strategy Principles

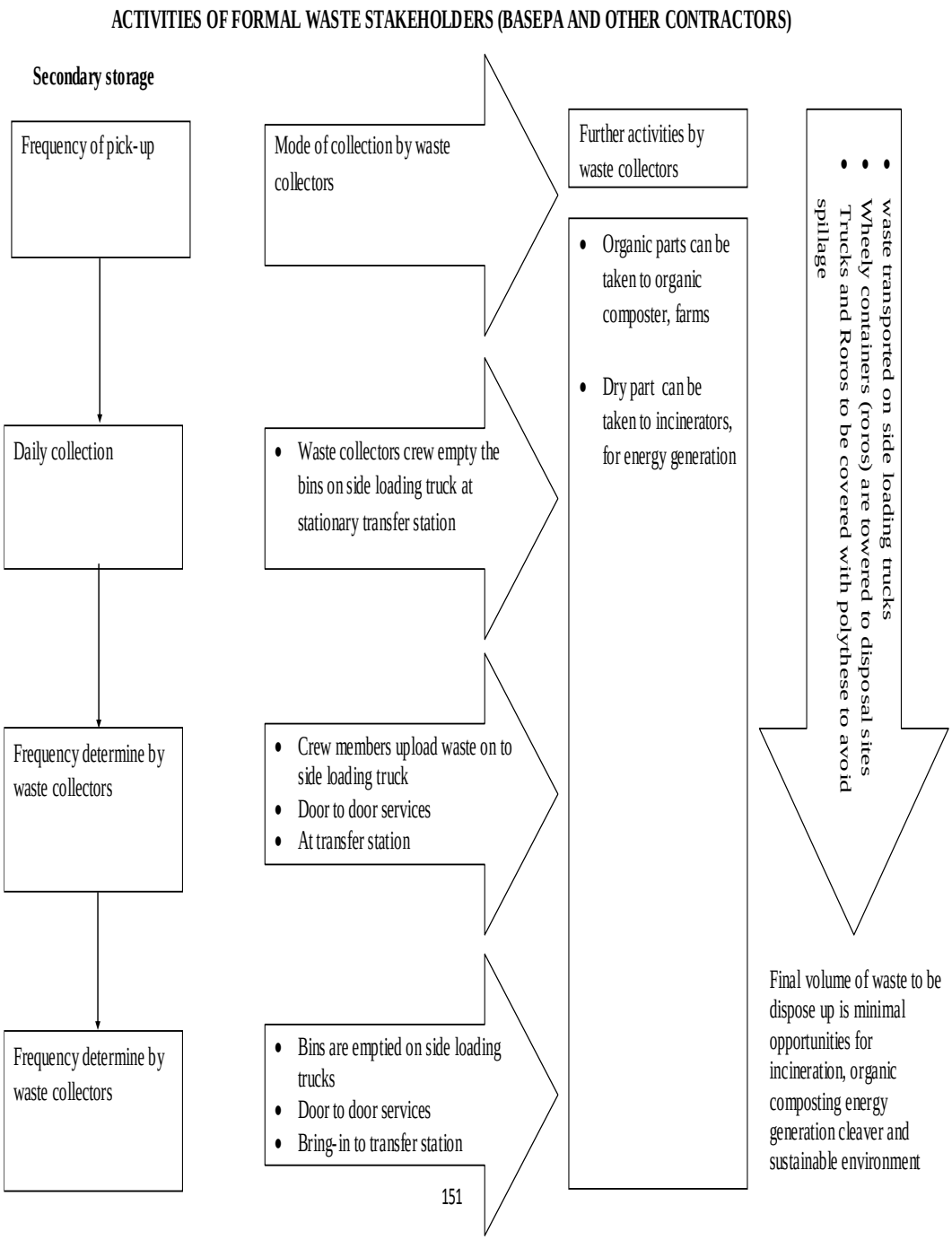
As shown in the diagrams below:

- **Strategy Objectives**; Accessibility; flexibility; and sustainability of household solid waste management
- **Scope**; public participation, private sector, disposal facility sitting, planning
- **Actors**; households, municipal agency, private contractors, ward leaders, NGO, CBO.
- **Technical Aspects**; no use of compactor trucks, movable and stationary transfer stations, use of side loading trucks, waste separation at source

DOMESTIC SOLID WASTE MANAGEMENT STRATEGY TEMPLATE

HOUSEHOLDERS ACTIVITIES





IV. CONCLUSION

Solid waste management in Nigerian urban centres was found to be what can be termed as "movement of the waste from one location to another". It is devoid of sustainable practices of reduce, reuse and recycle (3Rs) from generation, handling up to final disposal. From the studies, the average per capita waste generation for Nigerian urban centers stands at 0.54 kg/cap/day. According to the World Bank development indices report of 2016 the country's urban population was 90,385,385. The implications of this outcome indicates that the daily waste generation in Nigerian Urban areas amounts to 48,808,107.9 kg (53,801.8 tons) which needs to be treated and dispose up in an environmentally and sustainable manner.

This information is vital to policy makers, architects, engineers, city planners and environmentalist as world cities faces enormous environmental challenges in terms of climate change,

resource use and protection of the natural environment. UN SDGs. Improvements in SWM and 3Rs will substantially contribute to the better living conditions and better health of more than 2–3 billion people who currently lack services, prevent plastics entering the oceans, significantly contribute to climate change mitigation, and help restore terrestrial ecosystems. In the process, decent jobs will be created, which will support many people and their families on their way out of poverty (Rodic and Wilson 2017).

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