Review on Solid Waste Generation and Management in Sub-Saharan Africa: A Case Study of Nigeria

*1ORHORHORO, EK; 2OGHOGHORIE, O

1Department of Mechanical Engineering, College of Engineering, Igbinedion University, Okada, Nigeria
2Department of Mechanical Engineering, Faculty of Engineering, Benson Idahosa University, Benin City, Nigeria
*Corresponding Author Email: ejiroghene.orhorho@iuokada.edu.ng; Tel: +2348064699781

ABSTRACT: Nigeria just likes every other country in sub-Saharan Africa is faced with solid waste generation and management. Solid waste is dump indiscriminately and seen in huge heaps on any piece of unused land, around buildings, drainage system, institutions, playing ground, roads side, and in the open market places in major cities and towns. Living with solid wastes littered around seems to be an acceptable way of life among the people in this part of the world. This research work reported intensive review on solid wastes generation and management in this region using Nigeria as a case study. The application of knowledge of solid waste generation and management approach is crucial for inculcating a change of attitude towards improving the management of generated solid waste in this region. From the review, it was observed that biodegradable solid waste that can be managed via the biogas technology and landfill technology have the highest percentage fraction while the remaining fraction that comprised of non-biodegradable and combustible solid waste can be managed via other technology such incineration, gasification, pyrolysis, etc. Besides, the inefficient management of generated solid waste by individuals, households, institution, consumers and waste management companies can be attributed to inadequate information on waste management benefits, insufficient academic research and industry linkages, financial constraint, economic constraint, cultural constraint, lack of planning and projection, social constraint, lack of producers' involvement in waste management as well as poor implementation of government policies and lack of comprehensive legal framework.

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Solid waste is the useless and unwanted substances in solid state, discarded by members of the society. It can be defined as any product or substance that has no further use or value for the person or organization that owns it, and which is or will be discarded (Kolekara et al., 2016). Solid waste can be classified based on their source, such as; municipal solid waste, industrial solid waste and agricultural solid waste. Solid waste generation and management are major problems facing sub-Saharan Africa countries like Nigeria, Ghana, Cameroon, etc. Most cities and towns in this region spend 20-50% of their environmental budget on solid waste management and only 20-80% of the waste is collected. The standard of waste management in sub-Saharan Africa countries is at its lowest with inefficient storage and collection system, and the under-utilization of disposal sites. Thus, solid waste disposal has become a menace in sub-Saharan Africa countries because of their poor waste management policy. In nook and cranny of the major cities and towns in sub-Saharan Africa countries, one can see a rotting heap of solid waste in open places such as; markets, institutions, streets, drainage system, uncompleted buildings, etc. (Orhorhoro et al., 2016b). Poor management of solid waste in sub-Saharan Africa countries is a source of concern to the society. The generated waste poses a threat to urban management, defaces the aesthetics of the country’s cities and towns (Fig. 1), and a health hazard to citizens through the blockage of drainage systems, causing erosion and flooding. It is a breeding ground for mosquitoes, thus, posing a serious health risk to the populace sub-Saharan Africa countries.

*Corresponding Author Email: ejiroghene.orhorho@iuokada.edu.ng; Tel: +2348064699781
In this research work, a comprehensive review on solid waste generation and management was carried out in Nigeria being the most populated country in that region. The quantity of solid waste generated in Nigeria is increasing because of increase in her population that is estimated at 187,896,647 persons. Nigeria accounts for nearly half the total population of West Africa, and more than 15% of the total population of African. The population density in Nigeria is 205 per Km², and the total land area is 910,802 Km². Estimated 48.1 % of the population live in urban while the rest based in the rural area with farming as their major occupation. Nigeria population is equivalent to 2.48% of the total world population and is estimated to double that figure by the year 2050 (UNWPE, 2016). As a result of the quantity of solid waste generated from Nigeria cities and towns due to poor implementation of standards and lack of proper waste management policy, strategic centers of attraction in Nigeria are sometimes taken over by the messy nature of unattended heaps of solid wastes emanating from the society (Fig. 2) (Anwar et al., 2014; Orhorhoro et al., 2017a). City officials and town planners appear unable to combat unlawful dumping of solid waste, which is a clear violation of the clean Air and Health Edicts in environmental sanitation laws and regulations (Akintokun et al., 2011; Antanasijevic et al., 2013).

Fig. 2: Solid waste dump in major road, Lagos State, Nigeria

Solid Waste Generation: Solid waste is generated in all sorts of ways. However, the volume of solid wastes generated in Nigeria mainly depends on the consumption pattern, industrial and economic structures in place (Orhorhoro, 2014). According to Hoornweg and Bhada-Tata (2013), countries with fast growing economies are mostly faced with high volume of solid waste generation. For example, waste generated in China increased 9% annually from 1979 to 1995, a period associated with rapid economic growth, and this is expected to double by 2030 (Forbes Economy ranking in Africa in 2018). Nigeria has the best economy in Africa with an estimated $172 billion, followed by South Africa with $166.735 billion. Thus, if the report of Hoornweg and Bhada-Tata (2013) is anything to go by, more solid waste will be generated in Nigeria and this call for concern. Besides, different research work carried out in Nigeria to determine and evaluate the quantity of solid waste generated per day shown that Nigeria solid waste generation is at a daily rate of 0.43-0.66 kg/capital/day (Table 1).

Globally solid waste generation levels are approximately 1.3 billion tonnes per year and this is expected to increase by 2.2 billion tonnes per year by 2025. This represents a significant increase in per capita solid waste generation rates, from 1.2 to 1.42 kg per person per day in the next fifteen years (Igbinomwanhia, 2011a; Igbinomwanhia et al., 2011b; Hoornweg et al., 2013). Table 2 shows solid waste generation per capita by region, indicating the lower boundary and upper boundary for each region, as well as average kg per capita per day of waste generated within each region. Solid wastes generation in sub-Saharan Africa is approximately 62 million tonnes per year and it spans a wide range from 0.09 to 3.0 kg per person per day with an average of 0.65 kg/capital/day (Hoornweg et al., 2014). Figure 3 shows global waste generation per region. Table 3 shows estimates of solid waste generation for the year 2025 as expected according to current trends in population growth in each region.

**Table 1: Solid wastes generation in some major urban cities and towns in Nigeria (Igbinomwanhia, 2011a; Hoornweg et al., 2014; Titus, and Anim, 2014; Owamah et al., 2015; Igbinomwanhia et al., 2017; Orhorhoro et al., 2017a)**

<table>
<thead>
<tr>
<th>City</th>
<th>Population</th>
<th>Agency</th>
<th>Tonnage per Month</th>
<th>Density (kg/m²)</th>
<th>kg per capita per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benin</td>
<td>1,085,676</td>
<td>Lagos state management authority</td>
<td>255,556</td>
<td>294</td>
<td>0.43</td>
</tr>
<tr>
<td>Lagos</td>
<td>8,029,200</td>
<td>Kano state environmental protection agency</td>
<td>156,676</td>
<td>290</td>
<td>0.56</td>
</tr>
<tr>
<td>Ibadan</td>
<td>307,840</td>
<td>Oyo state environmental protection commission</td>
<td>135,391</td>
<td>330</td>
<td>0.51</td>
</tr>
<tr>
<td>Kaduna</td>
<td>1,458,900</td>
<td>Kaduna state environmental protection agency</td>
<td>114,443</td>
<td>320</td>
<td>0.58</td>
</tr>
<tr>
<td>Port Harcourt</td>
<td>1,053,900</td>
<td>Rivers state environmental protection agency</td>
<td>117,825</td>
<td>300</td>
<td>0.60</td>
</tr>
<tr>
<td>Makurdi</td>
<td>249,00</td>
<td>Urban development board</td>
<td>24,242</td>
<td>340</td>
<td>0.48</td>
</tr>
<tr>
<td>Onitsha</td>
<td>509,500</td>
<td>Anambra state environmental protection agency</td>
<td>84,137</td>
<td>310</td>
<td>0.53</td>
</tr>
<tr>
<td>Onitsha</td>
<td>509,500</td>
<td>Enugu state environmental protection agency</td>
<td>12,900</td>
<td>370</td>
<td>0.44</td>
</tr>
<tr>
<td>Abuja</td>
<td>159,900</td>
<td>Abuja state environmental protection agency</td>
<td>14,785</td>
<td>280</td>
<td>0.66</td>
</tr>
</tbody>
</table>

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Table 2: Solid waste generation per capita by region (Hoornweg et al., 2013)

<table>
<thead>
<tr>
<th>Region</th>
<th>Waste Generation Per Capita (kg/capita/day)</th>
<th>Lower Boundary</th>
<th>Upper Boundary</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Sub-Saharan Africa (S.AF)</td>
<td>0.09</td>
<td>3.0</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>East Asia Pacific (EAP)</td>
<td>0.44</td>
<td>4.3</td>
<td>0.95</td>
<td></td>
</tr>
<tr>
<td>Southern Asia (SA)</td>
<td>0.12</td>
<td>5.1</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>OECD member countries</td>
<td>1.10</td>
<td>3.7</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Middle East and North Africa (MENA)</td>
<td>0.16</td>
<td>5.7</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Latin America and the Caribbean (LAC)</td>
<td>0.11</td>
<td>5.5</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>East and Central Asia (ECA)</td>
<td>0.29</td>
<td>2.1</td>
<td>1.1</td>
<td></td>
</tr>
</tbody>
</table>

![Waste generation by region](image)

Table 3: Solid wastes generation projections for 2025 by region (Hoornweg et al., 2014)

<table>
<thead>
<tr>
<th>Region</th>
<th>Current Available Data</th>
<th>Current Available Data Projections for 2025</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Urban Population (millions)</td>
<td>Urban Solid Per Capital (Tons/day)</td>
</tr>
<tr>
<td>*S.AF</td>
<td>260</td>
<td>0.65</td>
</tr>
<tr>
<td>EAP</td>
<td>777</td>
<td>0.95</td>
</tr>
<tr>
<td>ECA</td>
<td>227</td>
<td>1.1</td>
</tr>
<tr>
<td>LAC</td>
<td>399</td>
<td>1.1</td>
</tr>
<tr>
<td>MENA</td>
<td>162</td>
<td>1.1</td>
</tr>
<tr>
<td>OECD</td>
<td>729</td>
<td>2.2</td>
</tr>
<tr>
<td>SA</td>
<td>426</td>
<td>0.45</td>
</tr>
<tr>
<td>Total</td>
<td>2,980</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Sources of Solid Wastes in Nigeria: The various sources of solid waste generated in Nigeria are summaries in Table 4.

Solid Waste Characterization: Solid waste characterization can be defined as the process by which the composition of different solid waste stream is grouped and analyzed (Sabejeje et al., 2014). Solid waste is heterogeneous in composition; thus, it is not expected to be consistent in composition. Several researchers reported different composition of solid waste generated in Nigeria as depicted in Fig. 4 (Oyelola, and Babatunde, 2008; Igbinomwanhia et al., 2011b; Owamah et al., 2015; Orhorhoro et al., 2017a). Organic solid waste account for over 50% of solid waste generated in Nigeria cities and towns with other solid waste components such as metals, plastic, leather waste, etc. estimated at different composition (Fig. 4). Solid wastes generated in Nigeria cities and towns generally consist of food remnants, plastics, paper, textile, metal, glass (Orhorhoro et al., 2017a). Igbinomwanhia (2011a) carried out research work on the status of waste management using Mushin Local Government Area, Lagos State, and Oredo Local Government Area, Benin, Edo State, both a major cities located in Nigeria. The selected areas for his research work are located at the geographical center of Lagos and Benin metropolis. A total weekly average of 2263.2Kg of domestic solid waste was generated in Lagos metropolis within the period of study. Based on this figure, a daily generation rate of 0.57kg per person per day (ppd.) was calculated for Lagos metropolis. Besides, a total 5373.61Kg of domestic solid waste was generated within the period in Benin metropolis, Nigeria. Base on this figure, a daily generation rate of 0.425kg per person per day (ppd.) was determined and evaluated. The percentage composition of solid waste generated was similar to the one obtained in other major cities and towns across Nigeria (Zavodsk, 2003; Owamah et al., 2015; Orhorhoro et al., 2017a). Also, in the research work carried out by Igbinomwanhia et al. (2017) entitled “Characterization of Domestic Solid Waste for the Determination of Waste Management Option in

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Amassoma, Bayelsa State, Nigeria”; the results obtained revealed that the total solid waste generated in Amassoma is 1115.2kg/day from domestic activities. Besides, analysis of the collected samples showed that 51.34% of compostable waste (garbage) which is biodegradable is generated, 33.62% of combustible waste and 15.04% of incombustible waste is generated in Ammasoma town. Their study also revealed that open dumpsite is the current solid waste disposal option in Amassoma. Although, engineering landfill could have been preferable to the open dumpsite but because of the geography of Amassoma being located in oil prone Niger Delta of Nigeria that is largely covered with water, if landfill system is adopted, it can lead to eutrophication. For that reason, they recommended integrated waste management programme incorporating recycling, composting and incineration with energy recovery.

Table 4: Sources of solid wastes generated in Nigeria (Benjamin et al., 2014; Ukwaba et al., 2018)

<table>
<thead>
<tr>
<th>Source</th>
<th>Typical Waste Generator</th>
<th>Type of Solid Waste Generated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>Single and multifamily dwellings</td>
<td>Food waste, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes (e.g., paints, aerosols, gas tanks, waste containing mercury, motor oil, cleaning agents), e-wastes (e.g., computers, phones, TVs).</td>
</tr>
<tr>
<td>Industrial</td>
<td>Light and heavy manufacturing, fabrication, construction sites, power and chemical plants.</td>
<td>Housekeeping waste, packaging, food waste, construction and demolition material, hazardous waste, ashes, special waste.</td>
</tr>
<tr>
<td>Institutional</td>
<td>Schools, hospitals (non-medical waste), prisons, government buildings, airports.</td>
<td>Paper, cardboard, plastics, wood, food waste, glass, metals, special waste, hazardous waste.</td>
</tr>
<tr>
<td>Construction and Demolition (C &amp; D)</td>
<td>New construction sites, road repair, renovation sites, demolition of buildings.</td>
<td>Wood, steel, concrete, dirt, bricks, tiles.</td>
</tr>
<tr>
<td>Municipal Services (MS)</td>
<td>Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants.</td>
<td>Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas, sludge.</td>
</tr>
<tr>
<td>Process</td>
<td>Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing.</td>
<td>Industrial process wastes, scrap materials, off-specification products, slag, tailings.</td>
</tr>
<tr>
<td>Agricultural</td>
<td>Crops, orchards, vineyards, dairies, feedlots, farms.</td>
<td>Crops, orchards, vineyards, dairies, feedlots, farms.</td>
</tr>
<tr>
<td>Medical waste</td>
<td>Hospitals, nursing homes, clinics.</td>
<td>Infectious waste (bandages, gloves, cultures, swabs, blood and body fluids), hazardous wastes (sharps, instruments, chemicals), radioactive wastes from cancer therapies, pharmaceutical wastes.</td>
</tr>
</tbody>
</table>

Fig. 4: Solid waste percentage composition generated daily in Nigeria cities and towns

Solid Waste Management: Solid waste management simply means all waste activities that are required to manage generated solid wastes effectively. It includes generation, control, storage, collection, transfer and transportation, processing and disposal of solid waste consistent with the best practices of public health,
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Solid Waste Management Hierarchy: Solid waste management hierarchy is shown in Fig. 5. If Nigeria can adopt the integrated solid waste management programme, the large volume of generated solid waste can be channeled into energy generation and other usage, thus making the environment friendly and healthy.

![Waste management hierarchy](image)

**Fig. 5: Waste management hierarchy**

**Source Reduction and Reuse:** Source reduction and reuse are solid waste management practice that encompasses all the activities premeditated to reduce the volume of solid waste generated, or toxicity of products throughout their life cycle. It involves the design and manufacture, use and disposal of products with minimum toxic content, minimum volume of material and/or a longer useful life. It takes various forms such as reusing or donating items, buying in bulk, reducing packaging, redesigning and reducing products (Oziegbe, 2015). According to McKendry (2002), specific examples of source reduction include:

1. The redesigning of products to use fewer materials (material substitution).
2. Reusing products and materials that have served the main purpose it was meant for (e.g., a refillable water bottle).
3. Extending the useful lifespan of products.

The following benefits can be obtained from source reduction and reuse (McKendry, 2002):

1. It helps in savings natural resource.
2. It brings about conservation of energy.
3. It helps in the reduction of pollution.
4. It brings about reduction in the toxicity of wastes.

**Recycling/Composting:** Solid waste recycling/composting is a waste management technology that converts solid wastes to reusable products. It involves activities such as collection of used, reused, or unused items that have been discarded and processing of it into usable products (Kreiger et al., 2014).

**Energy Recovery:** Energy recovery from solid wastes is the conversion of non-recyclable wastes materials into usable heat, electricity, or fuel through a variety of processes/technologies (i.e., combustion,
gasification, pyrolysis, etc.). This process is often called waste-to-energy (WTE). Energy recovery serves two major purposes (i.e., wastes control and energy production) (Thomson, 2010).

Treatment and Disposal: Landfills are the most common form of waste disposal. However, in Nigeria, lack of engineering landfill system, encourages open dumpsites as means of waste management. Landfill is an important component of an integrated waste management system. Landfills that accept municipal solid wastes are primarily regulated by state and local governments. Today’s landfills must meet stringent design, operation and closure requirements. Bio-methane of the landfill system can be collected and used as fuel. After a landfill is capped, the land may be used for recreation sites such as parks, golf courses, etc.

Biochemical Technology: Biochemical technology involves the breakdown of hemicellulose fraction. The two biochemical process options are anaerobic digestion (AD) and aerobic fermentation (Orhorhoro et al., 2016a; Orhorhoro et al., 2018a). In AD process, high moisture content (85-90%) biomass is converted into biogas by microorganisms in the absence of oxygen (Orhorhoro et al., 2017b; Orhorhoro et al., 2017bc). The raw biogas is purified before it can be used, and this is because of the presence of impurities such as hydrogen sulphide, dust, water, siloxane and halogenates hydrocarbons. These impurities if not removed can cause health problems, corrosion problems in processing, handling and storage facilities/equipment (Orhorhoro et al., 2018a).

Thermochemical Conversion of Solid Waste: Thermochemical conversion of solid waste embroils any of the following processes; combustion, gasification, pyrolysis (Lim et al., 2012). Combustion is used mostly for biomass with moisture content less than 50%. It converts the chemical energy stored in biomass into heat, mechanical power or electricity in stoves, furnaces, boilers, steam turbines or turbo – generators. The combustion technology is either fixed bed or fluidized bed systems. Solid waste can be co-fired in existing coal power plants or combusted in a dedicated combined heat and power (CHP) plants.

Gasification: Gasification is the conversion of the generated solid waste into combustible gas mixture by the partial oxidation of the waste at temperatures of about 800°C-900°C under a controlled amount of air. The produced gases consist of a mixture of carbon monoxide (CO) (18-20%), hydrogen (H₂) (18-20%), carbon dioxide (CO₂) (8-10%), methane (CH₄) (2-3%), small quantities of other light hydrocarbons (C₃H₈) and steam (H₂O) including nitrogen (N₂). The produced gases have low calorific value (4-6 MJ/Nm³) and can burnt directly or used as a fuel for gas engines and gas turbines. The composition of the gas is influenced by gasification conditions such as temperature and pressure (El-Emam et al., 2012).

Pyrolysis: Pyrolysis is a thermochemical decomposition of the generated solid waste at elevated temperature (350 to 550°C) in the absence of oxygen (or any halogen) to produce three fractions which include (Lim et al., 2012): i. Liquid fraction (often called bio-oil) ii. Solid (mostly ash) and iii. Gaseous fractions

Incineration: Incineration is a solid waste treatment technology that encompasses the combustion of organic substance contained in solid waste materials. The heat generated from the process can serve for power generation (El-Emam et al., 2012). Incineration and gasification technologies look similar in principle and operation. However, the energy produced from incineration is higher whereas combustible gas is often the main energy product from gasification.

Constraints to Solid Waste Management in Nigeria: Igbinomwanhia, and Ohwovooriole (2012) reported economic, financial, technical, institutional, social and cultural as the major constraint limiting residential solid waste management in Nigeria. In sub-Saharan Africa countries just like every other developing country has a weak economic base, thus, insufficient funds for development of sustainable solid waste management systems (Ogawa, 1996). Considering the economic requirement of the family in this region, a monthly income of less than or equal to $300 cannot meet the economic demand of the family. Hence, they do without the service of a solid waste disposal agent. They simply engaged in crude open dumping of solid waste in drainages, around the streets and open market places, any peace of unused land, open air burning without air pollution control. Besides, economic constraints also make them to patronize cart pushers who are not able to get to the approved designated dump sites where the solid waste are expected to be managed properly.

Generally, solid waste management is given a very low priority in Nigeria and other sub-Saharan Africa. Solid waste management is given very low priority in the budget due to limited finances (Omran, and Read, 2007). As a result, very limited funds are provided to the solid waste management sector by the governments. Thus, the levels of services required for protection of public health and the environment are not

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attained. Also, the user service charges collected by the disposal agents is too little to make any meaningful impact on solid waste management. Besides, users' ability to pay for the services is also limited by their income, and their willingness to pay for the services which are irregular and ineffective is not high either. More so, the end point of the solid waste does provide financial reward to waste disposal agent. Therefore, the only source of finance to the disposal agent is the user service charges.

In Nigeria and other sub-Saharan Africa countries, there is lack of human capitals at both the national and local levels with technical expertise necessary for solid waste management planning and operation (Zavodska, 2003). According to United Nations Commission on Sustainable Development (1997), there is lack of human capitals at both the state and local government level and the private sector with technical expertise necessary for solid waste management planning and implementation. Many officers in charge of solid waste management, particularly at the State Waste Management Board and other agencies handling the issues of waste, have little or no technical background or training in engineering or management. In fact all the problems that the solid waste Management system is faced with are exacerbated by the lack of trained personnel. More so, without adequately trained personnel, sustainable solid waste management planning and implementation is not realizable.

Furthermore, the negative perception of the society regarding the work which involves the handling of solid waste is another barrier. Such societal perception leads to low self-esteem for the workers especially the garbage men and in turn produces low working ethics and poor quality of their work. Where the society allows only a certain social class or group to deal with solid waste, the availability of work force for solid waste collection and disposal becomes constrained. Others major challenges facing solid waste management service delivery in Nigeria include (Tobore, 2016);

i. Lack of comprehensive legal framework and enforcement of the existing regulations
ii. Low investment (private) in infrastructure
iii. Inadequate human capacity for administrative and technical issues
iv. Wrong attitude of the public towards solid waste disposal
v. Cost recovery is low in most states and no funding
vi. Low data management and uncontrolled urbanization
vii. Uncoordinated institutional functions
viii. Low academic research and industry linkages
ix. Lack of the needed political will

Conclusion: This research work revealed that enough attention is not given to solid waste management in sub Saharan Africa countries. Challenges facing solid waste management in the study area and various technologies for managing generated solid wastes were identified. The major constraint facing solid waste management includes the lack of technical expertise, finance, culture, etc. Besides, feasible suggestions have been presented for improved solid waste management in the region. However, there is need for urgent attention to be paid to the issue of solid waste management as the adverse environmental effect resulting from the indiscriminate disposal of waste in the region is on the increase.

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