The Nigerian Journal of Energy & Environmental Economics
Department of Economics,
Nnamdi Azikiwe University, Awka,
Anambra State, Nigeria.

Web:www.aeeeng.org *ISSN 2006-8395*

URBANISATION OF BENIN CITY AND ITS IMPACT ON THE QUALITY OF SOILS IN SELECTED DUMPSITES

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Abstract

Benin City has experienced rapid population growth, urban expansion, and rising consumption, intensifying the challenge of inadequate solid waste management. This study investigates the impact of municipal solid waste (MSW) dumpsites on heavy metal concentrations in soils and private boreholes in selected parts of the city. Soil, borehole, and MSW composition data were obtained from the National Centre for Energy and Environment, University of Benin. Samples were analyzed for iron (Fe), zinc (Zn), copper (Cu), chromium (Cr), cadmium (Cd), and lead (Pb). Additionally, Landsat 8 satellite imagery (2010–2022) from the U.S. Geological Survey was employed to examine land cover dynamics. Findings revealed a steady increase in urban land use, from 23.97% in 2010 to its peak in 2022. Elevated heavy metal concentrations were recorded at both dumpsites, with Fe showing the highest mean level (232.73 mg/L at Oluko and 123.1 mg/L at Ikhueniro). While other metals were within World Health Organization (WHO) permissible limits for drinking water, Fe exceeded the recommended threshold. The composition of MSW followed the order: organic waste > paper > plastic > wood > glass > ceramic > metal, with organic waste accounting for 31.3% (47 kg) at Oluko and 27.9% (51 kg) at Ikhueniro. The study underscores the urgent need for public sensitization, waste-sorting awareness campaigns, and integration of MSW education into school curricula to promote sustainable waste management.

Keywords: Groundwater contamination, Heavy metals. MSW characterization, Municipal solid waste, soil pollution.

JEL Classification Codes: Q53, Q56, R11

1. Introduction

Municipal solid waste (MSW) generation and disposal is directly linked to consumption pattern, population growth, legislation/government policy, funding and people's level of awareness on waste sorting and the overall health and environmental consequences of MSW. For example, in a study carried out in China, Liu *et al.,* (2019) found that variations in consumption behaviors of residents lead to variations in the overall expenditure pattern, which is an important factor affecting the MSW volume. More so, a World Bank finding shows that with rapid population growth, annual waste generation is expected to increase by 73% from 2020 levels to 3.88 billion tonnes in 2050

(World Bank, 2022). On legislation and weak government policies, it has been revealed that the inability of governments to enforce waste and environmental legislation in many African countries has given rise to a culture of impunity as well as weakened the effectiveness of waste management in general (United Nations Environment Development, UNEP, 2014). In another study, Ho *et al.*, (2017) found that the rate of MSW generation has a direct link with several indicators of urbanization, including population growth and urban lifestyle. In addition, socioeconomic factors such as education, occupation, and family composition have been found to affect MSW generation (Bandara et al., 2007). Lee et al. (2016) for example found a correlation between the volume of waste generated and gross domestic product (GDP) per capita suggesting the higher the income level, the greater the volume of waste.

At the core MSW pollution is heavy metal contamination and bioaccumulation in soil, soil microorganisms and the water bodies. Soil is considered an important medium for organic waste disposal. Under certain conditions and depending on the properties of leachate from dumpsites, the organic waste can enhance the fertility of soil as well as improve the physical properties of soil. However, when the permissible level of the soil is reached, the bio-physical quality of soils around dumpsites can be severely compromised, leading to changes in the physical and chemical properties of the soil. Heavy Metals such as Cadmium, Chromium, Lead, Arsenic, Uranium, Mercury, NICKEL etc, are indicators of soil pollution. In their study, Zhao *et al.,* (2022) reported that heavy metals, namely arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb), copper (Cu), zinc (Zn), and nickel (Ni), are common pollutants in the soil environment. This type of contamination is biologically toxic, widely distributed, and persists long-term in the soil environment (Eigbike et al., 2024). Heavy metals find their way into the stream via many sources, such as industry, mining, agriculture, commercial and residential land-use activities. When present in the soil environment, Yan *et al*., (2020) reported that accumulation in plants, can take place via metal mobilization, root uptake, xylem loading, root-to-shoot transport, cellular compartmentation, and sequestration. Once taken up by a plant, humans can become exposed via ingestion of contaminated plants, food crops etc or indirectly through diffuse pollution or groundwater pollution. Mercury, lead, chromium, cadmium, and arsenic have been the most common heavy metals that induced human poisonings (Balali-Mood *et al.,* 2021). More so, Jaishankar *et al.,* (2014) reported that heavy metal toxicity can lower energy levels and damage the functioning of the brain, lungs, kidneys, liver, blood composition and other important organs. Long-term exposure can lead to gradually progressing physical, muscular, and neurological degenerative processes that imitate diseases such as multiple sclerosis, Parkinson's

disease, Alzheimer's disease and muscular dystrophy. Repeated long-term exposure of some metals and their compounds may even cause cancer (Jarup, 2003).

In view of these environmental and public health concerns, threats of climate change and coupled with increasing pressure from population expansion which has outweighed the capacity of municipal waste management authority to effectively managed MSW, there is need for continuous monitoring environmental change due to poor waste handling as findings from such studies will inform policy and scientific initiatives towards achieving sustainable environmental management. The aim of the present study hence to evaluate the effects of urbanizing Benin City on the quality of soils and borehole water around selected dumpsites.

2. Literature Review

In view of the environmental and health risks associated with handling and disposal of MSW in Nigeria, several studies have been carried out with view to achieve sustainable management of MSW. For example, Akintola *et al.*, (2021), Ibadan, Oyo State, Butu *et al*., (2020), Ezemonye *et al.,* (2022) in Akure, Ondo state Onyekwere and Nwakanma (2022) in Umuahia, Abia State, Yakubu and Udochukwu (2022) in some communities in Lagos Island, Lagos State, Azuka, and Ezeme (2023) in Obollo-Afor and Nsukka in Southeastern Nigeria, Alkali (2022), in Abuja, Ulakpa *et al.,* (2021), Boji-Boji Owa, Delta State, Terwase (2023) in n Jos Metropolis, Plateau State, Obianefo *et al.*, (2017) in Port Harcourt, Rivers State etc. Similarly in Benin City, studies on the impact of MSW dumpsites on soil quality has also been documented, such as Sam-Uroupa and Ogbeibu (2020), Igben and Ihayere (2021); Enerijiofi, and Ekhaise (2019): Onwuemele (2015), Agbebaku (2021), Iyebor *et al.,* (2020), Igbinosa and Aisien (2018), Omokaro *et al.,* (2023), Omorogieva and Igberase (2021), Ikpe *et al.,* (2019); Eghomwanre *et al.,* (2020): Aiwekhoe *et al.,* (2019), Adekola *et al.,* (2021), Otabor (2019), Ikpe *et al.,* (2020) etc. While some of these studies focused on perception, public awareness and determinants of MSW generation and management system (Onwuemele, 2015; Ikpe *et al.,* 2020; Adekola *et al.,* 2021; Agbebaku, 2021), others cantered on phyco-chemical properties of soils around dumpsites in Benin City, such as Igben and Ihayere (2021), Enerijiofi, and Ekhaise (2019), Eghomwanre *et al.,* (2020).

On Heavy Metal concentration in soils around dumpsites in Benin City, Sam-Uroupa and Ogbeibu (2020) investigated the effects of Solid Waste Disposal on heavy metal levels of soils around Ikhueniro dumpsite, Costain dumpsite Ugbiyoko and Omaghe dumpsites in Benin City. In another study Iyebor *et al.,* (2020) examined the levels of Heavy Metals in Oluko, Iguosa and Otofure dumpsites, Benin City. Igbinosa, and Aisien, (2018) also investigated Heavy Metal Levels, Physicochemical Properties and

Microbial Diversity of Soil Matrix from University Solid Waste Collection sites in Benin City, Nigeria. Aiwekhoe et al., (2019) examined heavy metal contamination of Otofure Dumpsite Environment near Benin City. Otabor (2019) also investigated the levels of heavy metals of soils around Ikhueniri and Iguomo dumpsites. Other study in Benin includes those of Omokaro *et al.,* (2023), it examined the concentration of Heavy Metal in Okra (Abelmoschus Esculentus) grown on Dumpsite Soil in Benin City, Nigeria, while Ikpe *et al.,* (2019) studied the effects of waste dumpsites on geotechnical properties of the underlying soils in wet season.

From the review of recent studies, it can be seen that while extensive studies on the impact of MSW dumpsites on soil quality have been done, studies relating solid waste to land use expansion and subsequent impact of heavy metal concentration is scanty. More so, studies on the impact of municipal solid waste dumpsites on heavy metal levels in Oluku (unapproved dumpsite) and Ikhueniro dumpsites (government approved) have been few, the most recent being the work of Sam-Uroupa and Ogbeibu (2020). Moreover, for a sustainable intervention on MSW management as well as initiatives to control the impact of poor MSW handling and disposal on the environment, there is need for regular monitoring of changes in relation to MSW pollution. The gaps in knowledge underscore the need for the present study.

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3. Study Area

Benin City is the capital of Edo State of Nigeria. It is located within Latitude 6^0 26' and 6^0 31'N Longitude 5^0 35' and 5^0 41'E (Fig. 1) (Balogun & Orimoogunje, 2015). According to the 2006 census, the population of Benin City was 1,085,892 with a growth rate of 2.8 percent (National Population Commission, 2010). Presently, the population of Benin City is over 1.5 million. With rapid population growth and soaring urbanization, the city is grappling with increased waste generation and the need for improved waste management. Both the Ikhueniro Open Waste Dump Site (government-approved dumpsite) and the Oluku dumpsite (unapproved dumpsite) which are chosen for this study are located within the city. While Ikhueniro Open Waste Dump Site is situated along Benin City Bypass near Benin-Agbor Express Road (803922.00 m E, 700182.00 m N), the Oluku dumpsite is located near the Benin-Akure Express Road (787847.16 m E, 715410.93 m N) (Google earth).

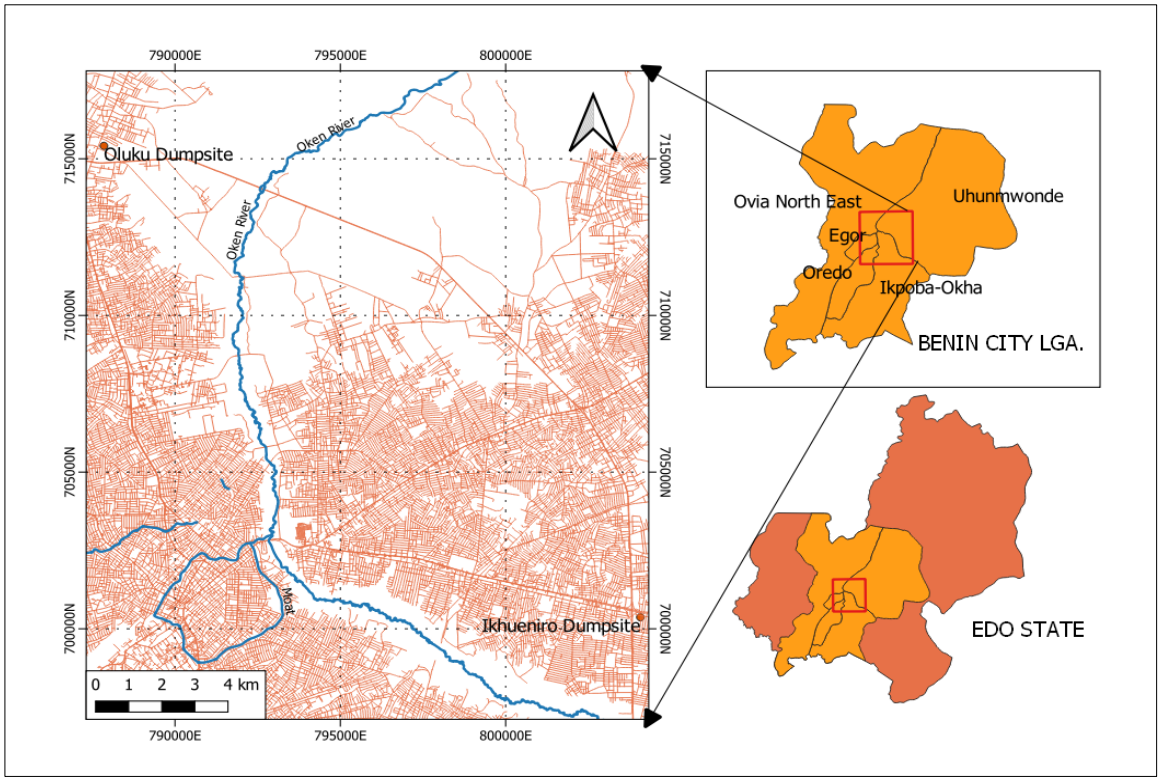


Figure 3.1: Map of Edo State showing Benin City on an Imaginary Boundary and the study dumpsites. Compiled using Open Street Map Database (2024)

Benin City is a rapidly expanding urban centre in Nigeria (Odjugo et al, 2015). It's increasing heterogeneous population results from rural–urban migration within Edo State as well as in-migration from other parts of Nigeria (Okolocha et al. 2021). The influx of migrants into the city is a direct result of sustained growth in the level of economic opportunities over the last decades. The main socio- economic activities in Benin City include transportation, trading, banking and related secondary manufacturing industries, brewing, plywood and furniture, pharmaceuticals, metal and bronze works. Benin City also plays host to several historical sites and monuments with enormous tourism potential thus heralding the influx of national and international tourists, necessitating the establishment of several hotels of reputable standards in the city (Fabolude and Aighewi, 2022). The array of socio-economic activities with its attendant strategic location as a nodal town contributes immensely to the rapid growth and development of the Benin City. The increasing population has led to disproportionate pressure on agricultural, commercial, industrial, recreational and residential land uses in the city (Ben-Amos, 2015).

3.1. Land use/land cover analysis/NDVI

3.1.1. Data Acquisition

Landsat 8 satellite imagery for Benin City spanning from 2010 to 2022 was acquired from the USGS Earth Explorer platform. This imagery provided a comprehensive view of the city's landscape over twelve years, allowing for a

detailed analysis of land cover changes. The images were reprocessed to correct for atmospheric effects, sensor artifacts, and geometric distortions. Image classification was done using ArcGIS software to categorize land cover classes such as built-up areas, vegetation, water bodies, and bare ground. Supervised classification was employed for this study. All the remote sensing and GIS operations including supervised classification, Image Processing and Manipulation were carried out at the GIS laboratory, National Centre for Energy and Environment, University of Benin.

3.1.2 Method using Google Earth Engine

The method adopted for this research was to create an integrated system for Google Earth Engine and Quantum GIS software. Google Earth Engine is a cloud-based platform with the capacity to improve the conventional procedure of data acquisition, preparation, comprehensive remote sensing analysis and result exportation for visualization using the QGIS.

3.1.3 Image Processing and Manipulation

Google Earth Engine code scripts were developed for the corresponding years for this research which are 2010, 2015, 2020, and 2022. These scripts were developed by combining several components from official Google resources and other references available to the public. The scripts consist of these four main sections;

a. Acquisition of Landsat surface reflectance image collection
b. Study area and sample selection geometries
c. Supervised classification with the CART model
d. Result exporting

3.1.4 Acquisition of Landsat Surface Reflectance Imageries

The first step in accessing and acquiring a data from the Google Earth Engine was to write a function to call the data scenes and make a composite image. This is called a stack or series of images referred the as Image Collections. In this case, the Landsat 7 and 8 raw scene collection were called and a composite was created from this collection. The next step was to specify the required date for this research, as such a filter function was scripted to limit the acquired image to only in it chosen location and date of interest. Cloud cover was masked out by a function to mask out the clouds using a pixel QA cloud band value provided within the products were utilized.

3.1.5 Study Area and Sampling Selection

The image was clipped to the study area with the clip function. Sampling points were visually selected and was categorize into five categories which are urban land, dense vegetation, light vegetation, water and barren land.

3.1.6 Supervised classification with CART

This research work employs a pixel-based supervised classification approach combined

with a machine learning algorithm. The composite imageries were analysed to identify the training and testing set polygons. The number of good samples was empirically examined by executing the script several times to obtain acceptable visual and statistical results. The samples were then utilized to achieve classification and regression trees (CART) on the Earth Engine platform (API Documentation). The classification results were then presented using a map function.

3.2 Solid Waste Characterization

Characterization of waste materials was done using Bernache Perez *et al.* (2001) method, which involves the direct sampling of solid waste from specific sources, a labour-intensive manual process of sorting, classifying and weighing all items in each sampling unit and a detailed recording of the data. Each of the waste samples from the source of generation was emptied on a polythene sheet (1 meter square) laid on the bare floor for sorting, weighed (net weight) with Kwonnie balance (20 kg) model TN – 1741874 and sorted into categories, as recommended by the ASTM test method D5231 – 92 (1988). The total wet weight of each waste category was determined and expressed in kilogram (kg).

3.3 Collection of Soil Samples

Soil samples were collected from the dumpsites at 0-15 cm and 15-30 cm depths with the aid of soil auger. On each site, soil samples were randomly collected at three-points ie. 20 meters from the dumpsite base, 10meter from the dumpsite base and the base of the dumpsite. Samples were collected in three replicates. At each dumpsite, a total of nineteen (19) soil samples were collected (nine sample at 0-15cm, nine samples from 15-30cm and a control point), making a total sample points of thirty-eight for the study. Samples were only collected during rainy season considering the effects of rainwater on pollutant migration. Control samples were collected 50 meters from the perimeter of the dumpsite. The soil samples collected were kept in polythene bags and labelled at the points of collection in order to avoid mix up of samples. The soil samples were taken to the laboratory for analysis immediately after collection in order to sustain their soil microorganisms. Laboratory analysis was done at National Centre for Energy and Environment, University of Benin, Benin City, Edo State. Parameters of interest include iron (Fe), Zinc (Zn), Copper (Cu), Chromium (Cr), Cadmium (Cd), Lead (Pb).

3.4 Ground Water Sample Collection

Groundwater data was obtained from the National Centre for Energy and Environment, University of Benin. A total of eight groundwater samples were collected from four wells (bore wells) within an area of 1.5km from the solid wastes dump. Four (4) samples (residences around Oluku area) were collected and another four (4) around residential buildings in Ikhueniro wastes dump site. Water samples were collected in three replicates. Hence at each site, a total of thirteen water samples were collected (i.e three

replicates of borehole water and a control point). On the whole, a total of twenty-six water samples were analysed in the study. Parameters of interest include iron (Fe), Zinc (Zn), Copper (Cu), Chromium (Cr), Cadmium (Cd), Lead (Pb). Borehole samples were collected at 375meter interval within the 1.5km distance (left and right side each dumpsite).

3.4.1. Sample Preparation

The water and soil samples collected were prepared as follows:

i. Preparation of Water Sample: - The water containerized and labelled before being taken to the laboratory for analysis. 50ml thoroughly shaken water samples from each sampling point were measured accurately into a beaker (representing one-third of the total weight) and digested with 5ml of concentrated HNO3 for a few hours on a hot plate at 100^{o}C till the solutions were reduced to less than 20ml by volume. The solutions were then transferred to 100ml plastic container and taken for heavy metals determination on Atomic Absorption Spectrometer (AAS).

ii. Preparation of soil samples (Digestion): - The soil samples were oven-dried (to avoid microbial effects), crushed and passed through a 2mm sieve and subjected to laboratory analyses using standard procedures. About 2.0g portion of dried sediment (representing one-third of the total weight) were digested in 15cm^3 of tri-acid mixture (HNO3, HCI and H2SO4 at 5:1:1 ration) at 800C until a transparent solution appeared. After cooling, the digested samples were filtered using what man No.41 filter paper and the filtrate was finally maintained at 50 cm^3 distilled water. The clear solutions were then poured into sample bottles for reading in the Atomic Absorption Spectrometer.

3.5 Laboratory Procedures

The analysis of the selected Heavy Metals was carried out using Atomic Absorption Spectrometer (AAS) (Bulk Scientific Model 200H AAS) after digestion of the sample at the Environmental Laboratory, National Centre for Energy and Environment, University of Benin. This method is suitable for both dissolved and total metals in soil and water. 100ml of the digest in each sample was run on the Atomic Absorption Spectrometer (AAS) which uses Air Acetylene Flame. By choosing the correct wavelength of the various elements and running a known standard curve of the various elements, the absorbance of the chemical elements present in the samples were determined. Using the standard absorbance of the various elements, the absorbance from the various heavy metals contained in the samples was converted to parts per million (ppm) or milligram per litre (mg/l) values as their levels of concentration.

3.6 Statistical Analysis

Groundwater data was obtained from the National Centre for Energy and Environment, University of Benin. A total of eight groundwater samples were collected from four wells (bore wells) within an area of 1.5km from the solid

wastes dump. Four (4) samples (residences around Oluku area) were collected and another four (4) around residential buildings in Ikhueniro wastes dump site. Water samples were collected in three replicates, hence at each site, a total of thirteen water samples were collected (i.e three replicates of borehole water and a control point). On the whole, a total of twenty-six water samples were analysed in the study. Parameters of interest include iron (Fe), Zinc (Zn), Copper (Cu), Chromium (Cr), Cadmium (Cd), Lead (Pb). Borehole samples were collected at 375meter interval within the 1.5km distance (left and right side each dumpsite).

4 Results Presentation

There are 5 land use land cover categories as illustrated in fig 4.2 namely urban land, light vegetation, dense vegetation, water and barren land which could be sparsely vegetated land. The imagery covers a 12-year period from 2010 to 2022 taken at 4 years intervals precisely 2010, 2014, 2018 and 2022. Urban development is extending towards the study dumpsites over time and as at the year 2022, both dump sites especially Ikuenero is surrounded by urban development as illustrated in Figure 4.2.

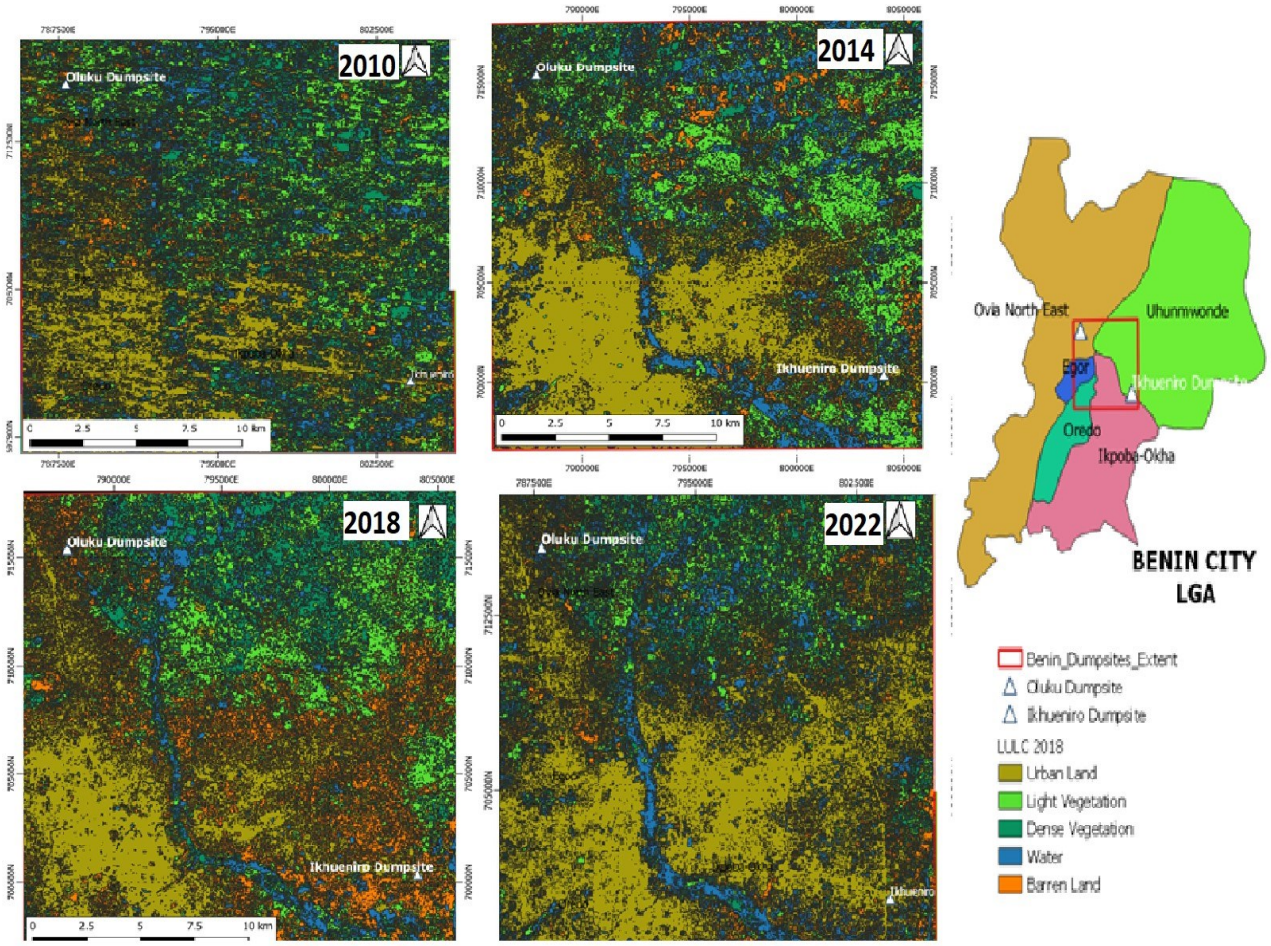


Fig 4.2: Land use/Land cover (LULC) for Oluku and Ikhuenero dumsites and Environs over the years from 2010 to 2022

Source: Author's Laboratory Work (2023)

Figure 4.3 further illustrates increasing urbanization within the area of interest over time with 2010 having lowest urban land use of 23.97%. Urban land use continued to increase through 2014 and 2018 until 2022, which recorded the highest urban land in 2022. On the other hand, the highest vegetative cover was recorded in 2010, which is 28.62% for light vegetation and 22.62% for dense vegetation.

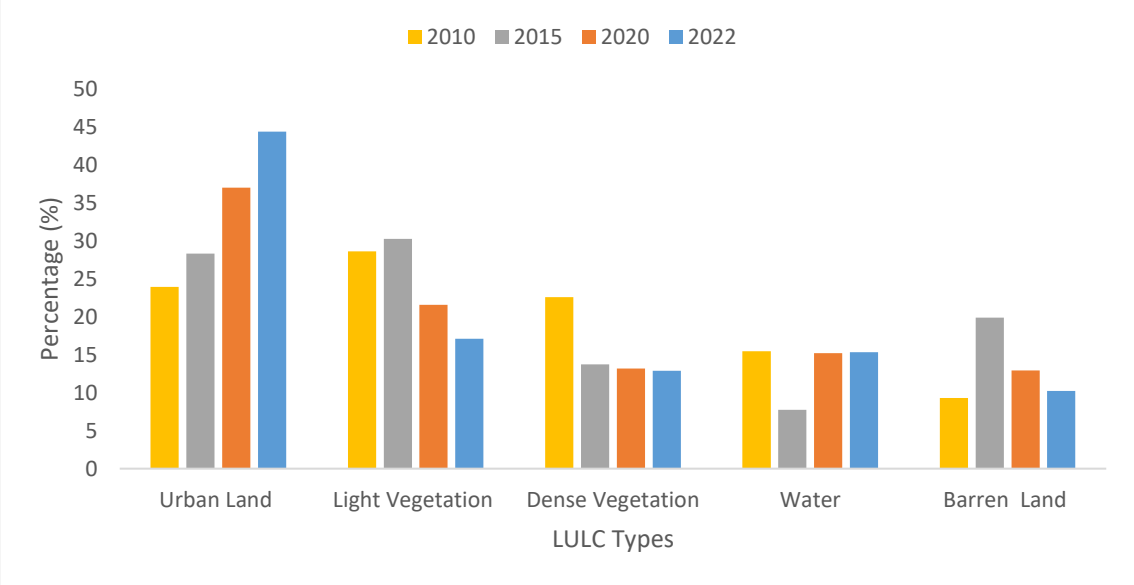


Fig. 4.3: Graphical presentation of % variation in LULU over the years
Source: Author's Fieldwork (2023)

High concentrations of heavy metals in soils at both dumpsites are observed, with Fe having the highest mean concentration of 232.73mgl recorded at Oluko dump site (Table 4.1). This was higher than the mean concentration of Fe (123.1mgl) recorded at Ikhueniro dump site (Table 4. 2). These values for Fe are generally higher than the concentration observed in the control samples of Oluku and ikhueniro (3.9mgl). More so in Tables 4.3 and 4.4, except iron which was above the maximum permissible limit for drinking water according to the WHO, other heavy metals investigated are within the WHO permissible limits.

Table 4.1: Heavy metal concentration in soil samples around Oluku dumpsite (mgl)

Location	Fe	Zn	Cu	Cr	Cd	Pb
Dumpsite Base	490.3	94.3	24.1	6.7	1.8	9.8
10m from the Dumpsite Base	202.2	19.9	12.1	3.2	1.2	6.5
20m from the Dumpsite Base	5.7	6.8	6.1	2.4	0.9	4.0
Mean	232.73	40.33	14.1	4.1	1.3	6.76
Control sample	**3.9**	**3.6**	**3.31**	**1.6**	**0.4**	**2.1**

Source: Author's Fieldwork (2023)

Table 4.2: Heavy metal concentration in soil samples around Ikhueniro dumpsite (mgl)

Location	Fe	Zn	Cu	Cr	Cd	Pb
Dumpsite Base	310.7	66.5	3.9	4.1	2.9	9.3
10m from the Dumpsite Base	46.3	83	2.21	3.9	1.8	4.3
20m from the Dumpsite Base	3.4	27.2	1.03	2.8	0.9	3.8
Mean	120.1	58.9	2.38	3.6	1.86	5.8
Control sample	**3.9**	**3.6**	**3.31**	**1.6**	**0.4**	**2.1**

Source: Author's Fieldwork (2023)

Table 4.3: Heavy metal concentration in water (boreholes) around Oluku dumpsite area (mgl)

Location	Fe	Zn	Cu	Cr	Cd	Pb
H01	0.945	0.514	0.041	0.018	0.041	0.031
H02	1.504	0.688	0.072	0.040	0.072	0.050
H03	1.240	0.512	0.061	0.021	0.061	0.038
H04	0.756	0.409	0.031	0.013	0.031	0.024
WHO	**0.3**	**5.0**	**1.0**	**0.05**	**0.005**	**0.05**

Borehole samples taken at 1.5km from the dumpsite: Source: Author's Fieldwork (2023)

Table 4.4: Heavy metal concentration in water (boreholes) around Ikhueniro dumpsite area (mgl)

Location	Fe	Zn	Cu	Cr	Cd	Pb
H01	1.181	0.570	0.047	0.025	0.018	0.038
H02	1.983	0.705	0.081	0.042	0.028	0.057
H03	1.462	0.633	0.069	0.030	0.021	0.043
H04	0.896	0.471	0.039	0.022	0.014	0.031
WHO	**0.3**	**5.0**	**1.0**	**0.05**	**0.005**	**0.05**

Borehole samples taken at 1.5km from the dumpsite: Source: Author's Fieldwork (2023)

Study of the characteristics of waste in both dump sites as illustrated in Figures 4.4 and 4.5, shows the following dominance sequence from highest to least; organic waste>paper>plastic>wood>glass>ceramic>metal. The frequency of organic waste for Oluku and Ikhueniro dump sites was 47kg (31.3%) and 51kg (27.9%) respectively.

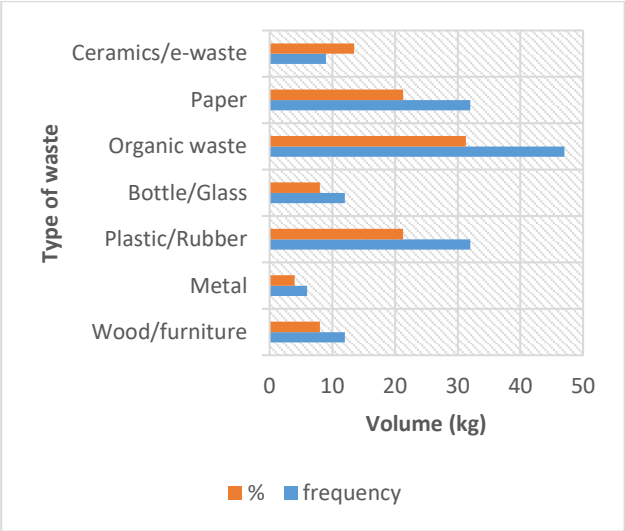


Fig. 4.4: Composition of waste generated in Oluko dumpsite (Kg)
Source: Author's Fieldwork (2023)

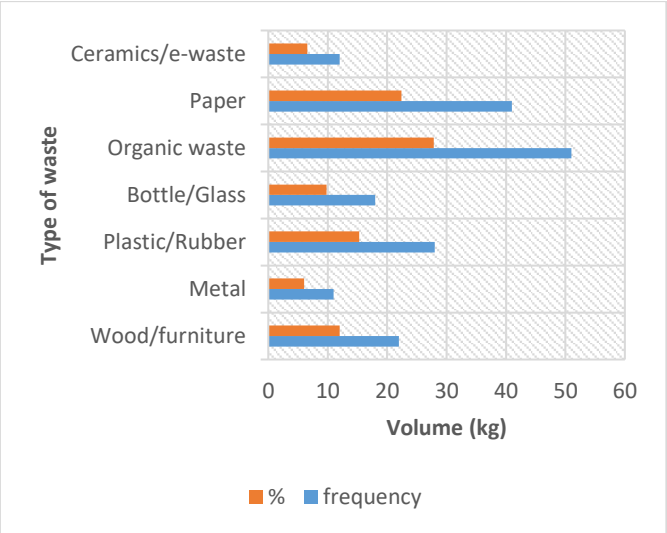


Fig. 4.5: Composition of waste generated in Ikhueniro dumpsite (Kg)
Source: Author's Fieldwork (2023)

Table 4.5: One way Analysis of Variance for variation in heavy metal levels in soil sample at different points around Oluku dumpsite

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	***F crit***
Between Groups	123363.8	5	24672.76	2.39799	0.099596	**3.105875**
Within Groups	123467.2	12	10288.94			
Total	**246831**	**17**				

Variation is not significant at p>0.05, d = 0.099: Significant level established at 0.05 level of confidence
Source: Author's Fieldwork (2023)

Table 4.6: One way Analysis of Variance for variation in heavy metal levels in soil sample at different points around Ikheniro dumpsite

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	***F crit***
Between Groups	35308.14	5	7061.628	1.485022	0.265533	**3.105875**
Within Groups	57062.8	12	4755.233			
Total	**92370.93**	**17**				

Variation is not significant at and p>0.05, d = 0.099: Source: Author's Fieldwork (2023)

Table 4.7: t-Test: Paired Two Sample for Means *Heavy metals in soil at Oluku and Ikheinero dumpsite*

	Heavy metals in soil at Oluku dumpsite	*Heavy metals in soil at Ikheinero dumpsite*
Mean	49.88667	**32.10667**
Variance	8224.138	**2352.783**
Observations	6	**6**
Pearson Correlation	0.945985	
Hypothesized Mean Difference	0	
df	5	
t Stat	0.917241	
P(T<=t) one-tail	0.200548	
t Critical one-tail	2.015048	
P(T<=t) two-tail	0.401095	
t Critical two-tail	**2.570582**	

Difference is not significant at p>0.05, d = 0.200: Source: Author's Fieldwork (2023)

5 Discussion of Findings

In Figs 4.2 & 4.3, it can be seen that Benin City has witnessed tremendous expansion in urban landuse. This observation confirms a recent study by Fabolude and Aighewi (2022) that about 284.56 km^2 of forest lands in Benin City were lost over a 32-year period (1987-2019), while built-up and barren lands increased rapidly by 153.96km^2 and 81.58km^2, respectively. The study went on to project that by 2050, the built-up area is expected to increase by 236.92km^2, while barren land is expected to maintain its percentage cover. Grassland increased by 52.16 km^2, while water decreased by 3.60 km^2, both of these classes are expected to decrease by 157.58km^2 and 0.45km^2 by 2050, respectively. In another study, Olajuyigbe (2016) has attributed the rapid urbanization of Benin City to establishment of institutions of higher learning and the accompanying employment opportunities, relatively low housing rents and low cost of land in the City. Hence the City becomes more urbanized, more pressure is exerted on available human and natural resources, leading to urban decay, breaking of basic services such as potable water/ electricity, supply, affordable housing, and even waste disposal/management systems. Waste generation has a direct link with urban lifestyle, income level and population size etc. Hence more waste is expected in urban settlements than their rural counterpart. Moreover, several authors have established a connection between urbanization, MSW generation and disposal problems. For example, according to the compositional

analysis, the higher the population density in a region, the greater the volume of garbage produced and, consequently, the infrastructure necessary for waste management (Voukkali *et al.,* 2023). In similar studies Gutberlet (2016) and Gutberlet (2018) reported that increased income enables consumers to purchase household appliances, electronics, cars, and other items that mark affluent lifestyles, including the consumption of more packaged food items and organic foods, all of which would be later regarded as waste.

All the heavy metals in soil samples exceeded the value obtained at the control points and these patterns are in line with other studies which reported that dumping of waste as a potential source of leachates contain melted organic matter, inorganic compounds (such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals like cadmium, chromium, copper, lead, zinc and nickel) and can easily infiltrate and pollute the soil and ground water (Aboyeji and Eigbokhan, 2016, Essien *et al.,* 2019; Ibrahim *et al.,* 2020; Na and Sirivithayapakorn, 2021; Gujre *et al.,* 2021). In similar studies, Saudi *et al.,* (2021) and Balilo et al., (2023) found that the concentrations of heavy metals such as Fe, Mn, Zn, Cr and Cu in decomposed solid waste were relatively high, which might be due to more metallic waste in the study area. The results of another study carried out at dumpsites in Nigeria also showed that there is heavy metal contamination in the soil around active landfills and abandoned landfills, but it is more in the soil around active landfills, so there are a health and ecological risk in the soil around landfills Afolabi and Eludoyin (2021).

Leachate is any substance that has seeped from decomposed wastes, dissolved or suspended materials (Essien et al., 2022) and is known to be produced at dumpsites when the water mixes mostly with waste dumps (Chinade *et al.,* 2017; Mojiri *et al.,* 2017). According to Michalska *et al.,* (2019), in certain dumpsites, the leachate is comprised of fluid which has penetrated the open landfill from diverse external sources, including soil erosion, groundwater, precipitation, and wastewater generated from the decomposition of organic waste. Hence leachates from municipal landfills have been reported to release toxic metals into the environment, posing serious threats to nearby lands and groundwater, and then to surface water (Essien *et al.,* 2019). The presence of iron (Fe) in MSW can be attributed to household equipment made in iron dumped in the landfill. Iron and Zinc are metal that is normally found in small amounts in nature. They are used in many commercial industries and can be released into the environment during mining and smelting (metal processing) activities. Mining, smelting metals (like zinc, lead and cadmium) and steel production, as well as burning coal and certain wastes can also release zinc into the environment.

Other studies have argued that metal-bearing solids at contaminated sites can originate from a wide variety of anthropogenic sources in the form of metal mine tailings, disposal of high metal wastes in improperly protected landfills, leaded gasoline and lead-based paints, land application of fertilizer, animal manures, biosolids (sewage sludge), compost, pesticides, coal combustion residues, petrochemicals, and atmospheric deposition (Basta *et al*., 2005; Raymond *et al.,* 2011). The author concluded that the higher concentration of Pb, Cu, Cd close to the landfill can be associated with industrial/chemical waste disposed of in the landfill (Parth *et al.,* 2011) or waste products containing batteries, food packaging materials, PVC materials, and insecticides (Amerh *et al.,* 2020). Saudi *et al.* (2021) pointed out that Pb, Cd, Cu, Cr, and Ni are potentially toxic to plants and animals and have been shown to accumulate in the food chain.

According to Adedara, *et al.,* (2013), the leachate produced from the municipal solid waste residues can easily leak into soil and water bodies and when consumed by animals transferred to humans through the food chain; they can also serve as a potent source of pollution for both soil and underground water. To further buttress the findings of the study, several studies have investigated soil contamination with heavy metals and found that landfill leachate is a source of heavy metal pollution in soil and water sources and their results have shown that many soils near industries, landfill sites are contaminated (Liu *et al.,* 2013; Kasassi *et al.,* 2008). The toxicity of leachate on human cells shows the importance of this source of pollution, which releases pollutants into the soil and water sources (Jabłońska-Trypuć, *et al.,* 2021). Heavy metal pollution and toxicity have been reported to severely inhibit the growth, yield, and quality of cereals, forages, and fruit crops via interfering in their physiological, cellular, and biochemical attributes, such as inhibition of photosynthesis, cell division, energy production, and protein synthesis (Khan *et al.,* 2018; Khan *et al.,* 2019). Similarly, studies have reported that heavy metals are considered the most dangerous among numerous soil pollutants due to their persistency and toxicity in the water–soil–plant environment (Villatoro-Pulido *et al.,* 2013; Akhter *et al.,* 2022).

Cr for example is highly toxic at higher concentrations to plants, animals, and human health and is a major source of carcinogenic disorders (Haider *et al.,* 2021). Cadmium is readily soluble in water, easily absorbed by plants, and is a serious environmental pollutant in agroecosystems (Duan *et al.,* 2020). On the other hand, higher amounts of Cu in the soil pose serious risks to the terrestrial ecosystem as well as to the health of both animals and people (Hussain *et al.,* 2022). In the past, several studies have been conducted to quantify the health risks associated with the ingestion of heavy metals, including Cu and Cd, by consuming contaminated food crops (Liu et al., 2005;

Ilechukwu *et al.,* 2021). For plants, many heavy metals are crucial microelements and are subsequently involved in a varied assortment of enzymatic redox responses. Root nodulation was inhibited, and the quantity of useful nodules significantly decreased (Chen *et al.,* 2022). Some of these nutrient elements have a defensive role contrary to the poisonous effects of Cd stress (Ashfaq *et al.,* 2022). Bioaccumulation of heavy metals might increase the pollution load in the soil rhizosphere, compromise the human and ruminant immune system, and result in some neurological problems, kidney failure, digestive system and heart disease (Akhtar, *et al.,* 2022).

The levels of heavy metals in water samples (borehole) were within WHO permissible limits for drinking water, except iron (Fe). Excessive quantities of Fe in the water results in an overload that might result in diabetes, hemochromatosis, stomach issues, and nausea. The liver, pancreas, and heart can all be harmed by it (Regan, 2009). Other studies have shown that iron in drinking water that is highly bioavailable could be absorbed as high as 40% (Worwood *et al.,* 1996; McKenna *et al.,* 2003). A study in Bangladesh suggested a positive association between groundwater iron contents (between above or below 1 mg /L) and linear growth of children with iron deficiency (Briend *et al.,* 1990). However, excessive body iron may be an issue of concern because of a possible association with several chronic diseases, such as heart disease (Salonen *et al.,* 1992; Klipstein-Grobusch, 1999) and diabetes (Tuomainen *et al.,* 1997; Salonen 1998).

The fact that predominates type of waste in the study area is organic waste, confirms the findings of other studies in Africa and parts of Asia (Ojeda-Benítez *et al.,* 2008, Toledo and Lujan, 2008; Salamatu and Safianu, 2017). For example, Denise *et al.,* (2023) reported the predominance of the organic fraction (63%). Another study in some developing cities of Africa and Asia also reported above 60% of organic fraction (Zia *et al.,* 2017). Household or municipal wastes are usually generated from variable sources where different human activities are encountered. Several studies reported that the municipal solid waste that are generated from the developing countries are mainly from households (55–80%), followed by market or commercial areas (10–30%) (Hussein *et al.*, 2018). Another study also reported the weighted average percentage of the waste fractions for university of Nigeria Nsukka Campus as 37.66%, 20.23%, 6.65%, 24.86%, 3.33% and 7.28% for paper, plastic, metal, organic, glass and others respectively. The waste fractions are generated in a decreasing order as follows: paper (37.66%), organic (24.86%), plastic (20.23%). metal (6.65%), others (7.28%) and glass (3.33%) (Nwoke et al., 2022). This underscores the importance of paper and plastic wastes as important components of MSW in Nigeria as also reflected in this study. Tables 4.5 and 4.6 shows there is no statistically significant differences in heavy metal concentration

between soil samples at different distance at p>0.05, d = 0.099 around the Oluku dumpsite and p>0.05, d = 0.099 at Ikheniro dumpsite. This does not mean that there is no difference, but that the difference is not significant. The statistical difference in the concentration of heavy metals in the mean soil sample between the two dumpsites were tested using student t test and the result is shown in Table 4.7. At p>0.05, d = 0.200 there is no significant difference between heavy metal levels in soils between the two dumpsites.

6 Conclusion and Recommendations

The present study investigated that impact of Solid Waste on the Soil Quality in Benin City, Edo State, Nigeria, using oluku and Ikhueniro dumpsites, taking into consideration the effects of expanding settlements around these dumpsites. Landsat 8 satellite imagery for Benin City spanning from 2022 back to 2010 was acquired from the USGS Earth Explorer platform. The study established an increasing urban trend in Benin Predominate type of waste in the study area is organic waste, followed by paper and plastic wastes, all of which are indicators of urban lifestyle and population expansion. All the heavy metals in soil samples exceeded the values obtained at the control points and these patterns are in line with other studies which reported that dumping of waste as a potential source of leachates contain melted organic matter, inorganic compounds. There were no statistically significant differences in heavy metal concentration between soil samples at different distances at p>0.05, d = 0.099 around the Oluku dumpsite and p>0.05, d = 0.099 at Ikheniro dumpsite. More so, the statistical difference in the concentration of heavy metals in the mean soil sample between the two dumpsites were tested using student t test and the result is that at p>0.05, d = 0.200 there is no significant difference between heavy metal levels in soils between the two dumpsites.

The current waste management practices in the study are flawed and not sustainable because a large amount of solid waste end up in open dumps or landfills many of which are unapproved dumpsites. To exacerbate this issue is the fact that the practice of household sorting is still not popular, hence it is not uncommon to find waste in commingled form. There is therefore the need for more sensitization and awareness creation programmes to enlighten the public on the importance of solid waste sorting. Schools should also develop curriculum on MSW sorting as a way of promoting early awareness and standard practices. There is also a need for strict enforcement of environmental regulations and regular monitoring for compliance to environmental standards, monitoring of civic responsibilities for sustainable waste storage, collection, and disposal.

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