Chapter

Municipal Solid Waste Management and the Inland Water Bodies: Nigerian Perspectives

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Abstract

Municipal solid waste (MSW) composition, natural transformation, dynamics and impacts on inland water bodies in Nigeria were examined, using dumpsites and landfills as the common markers. Nigeria is estimated to have over 178.5 million people and kg/capita/day of 0.26–1.02 MSW, projected to increase with the expansion of the economy which is in need of better articulated MSW management strategies. The enormous natural inland surface and groundwater resources are daily challenged directly and indirectly, through decline in physical, chemical and biological quality. Solid waste disposal along the waterways and leachates from natural activities on materials at dumpsites and landfills was strongly identified and recognized as the source of pollutant inputs. The immediate and projected public health consequences in changes in inland waters were provided for resident aquatic organisms, some of which serves as food for resident human populations that are largely dependent on these water bodies for their daily water requirements.

Keywords: Nigeria, inland water bodies, municipal solid wastes, water quality, public health

1. Introduction

Municipal solid wastes (MSW) refer to all wastes generated, collected, transported and disposed of within the jurisdiction of a municipal authority. In most cases, it comprises mainly food waste, discarded materials from residential areas, street sweepings, commercial and institutional nonhazardous wastes as well as (in some countries) construction and demolition waste.

MSW has been variously described as aggregation of unwanted materials generated from a range of human-related activities denominated from domestic to production. The origin of what is regarded as MSW can be closely associated with the earliest attempts by humans to transit from migrant to settler modes of living, which imposed the need to modify or change the character of raw or primary materials available to support or sustain the new modes of living and originating human activity.

Nigeria is the dominant country in West Africa, accounting for 47% of West Africa's population, with gross domestic product (GDP) growth at an average rate of 5.7% per year between 2006 and 2016, facilitated by volatile oil prices to a highest of 8% in 2006 and lowest of −1.5% in 2016; Human Development Index value also increased by 13.1% between 2005 and 2015 [1]. However, the country continues to face massive developmental challenges including, but not limited to, human development indicators and the living conditions of the population. Last collected in 2012 by the Nigeria National Bureau of Statistics, the total population of citizens in Nigeria was around 166.2 million people. In 2016, it was estimated to have over 178.5 million people although the United Nations' projections have placed the population as high as 186 million.

While MSW is generally associated with urbanization, recent developments in manufacturing processes have lowered the cost of production, enhancing the ability of manufacturers to produce goods that captures different income groups in population. The resultant effects are that areas hitherto considered as rural areas now experience both technological and economic penetrations. These penetrations will be accompanied by the penetration of MSW problems, hitherto restricted to urban centres. The developmental pressure experienced by major Nigeria cities has precipitated the upsurge in establishment of satellite towns, with attendant increase in human activity range and hence of waste generation.

Nigeria is considered one of the countries endowed with appreciable natural water resources in the world with the presence of the Niger River which is the third largest in Africa [2]. Natural water resources in Nigeria include enormous yearly rainfall, large surface bodies of water of rivers, streams and lakes, as well as in abundant reservoirs of underground water whose extent and distribution have not been fully assessed. The country is well drained with a reasonably close network of rivers and streams (**Figure 1**). Some of these rivers, particularly the smaller ones, are, however, seasonal, especially in the northern parts of the country where the rainy season is only 3 or 4 months in duration. In addition, there are natural water bodies like lakes, ponds as well as lagoons, particularly in the coastal areas [3–5]. The hydrology of Nigeria is dominated by two great river systems, the Niger-Benue and the Chad systems. With the exception of a few rivers that empty directly into the Atlantic Ocean (Cross River, Ogun, Oshun, Imo, Qua Iboe and a few others),

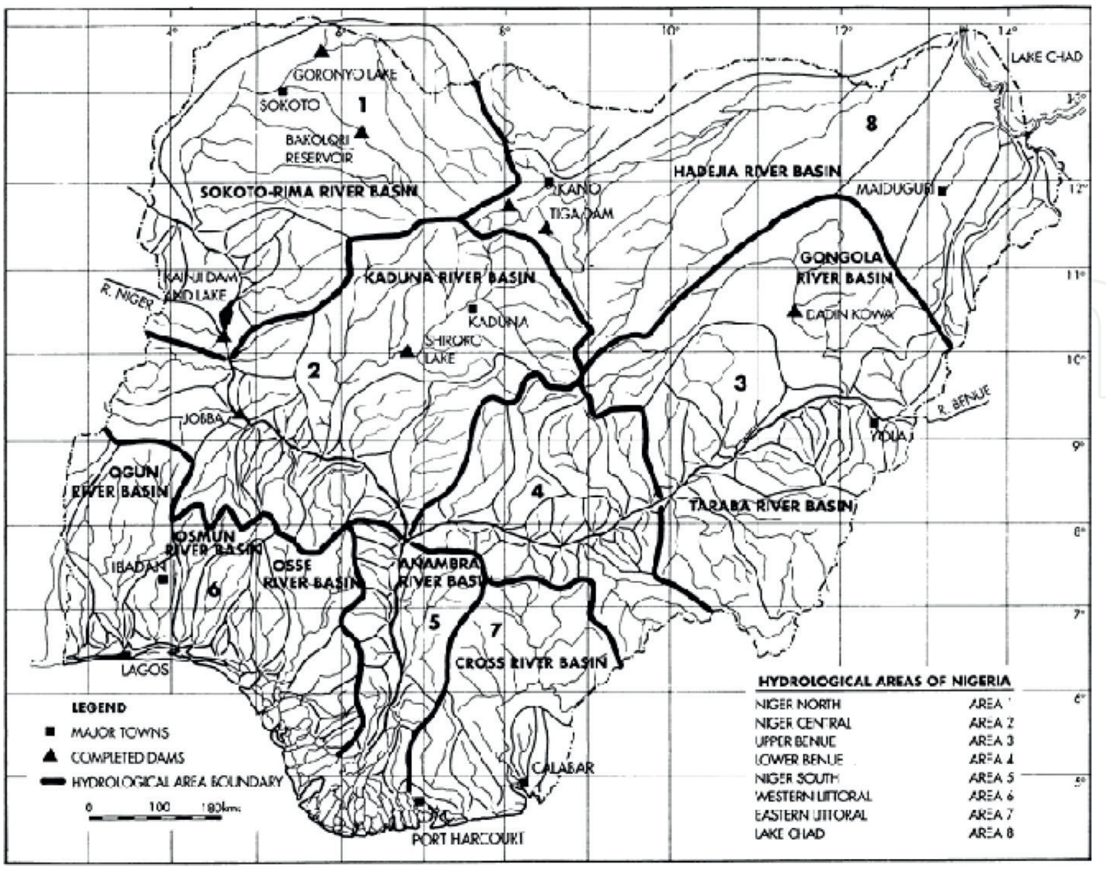

Figure 1.
Inland surface water resources of Nigeria (Source: [3, 4]).

all other flowing waters ultimately find their way into the Chad Basin or down the lower Niger to the sea. Nigeria lies between longitudes 2° 49′E and 14° 37′E and latitudes 4° 16′N and 13° 52′ North of the equator. The climate is tropical, characterized by high temperatures and humidity as well as marked wet and dry seasons, though there are variations between south and north. Total rainfall decreases from the coast northwards. The south (below latitude 8°N) has an annual rainfall ranging between 1500 and 4000 mm and the extreme north between 500 and 1000 mm.

The country has a vast expanse of inland freshwater and brackish ecosystems with an extensive mangrove ecosystem of which a great proportion lies within the Niger Delta. Freshwaters start at the northern limit of the mangrove ecosystems and extend to the Sahelian region. The major rivers, estimated at about 10,812,400 hectares, make up about 11.5% of the total surface area of Nigeria which is estimated to be approximately 94,185,000 hectares. Lakes and reservoirs have a total surface area of 853,600 ha and represent about 1% of the total area of Nigeria. Thus the total surface area of water bodies in Nigeria, excluding deltas, estuaries and miscellaneous wetlands, is estimated to be about 14,991,900 ha or 149,919 km^2 and constitutes about 15.9% of the total area of Nigeria. This review provided an insight on interactions between MSW, as indexed by dumpsites and landfills in Nigeria, and inland surface and groundwater in their vicinity.

2. Municipal solid waste generation in Nigeria

Generation of MSW in Nigeria is a daily occurrence, arising from diverse and varied human activities; hence the character of solid waste generated is never homogenous (**Plate 1a**–**k**). The differences can be a function of several indicators which include but not limited to originating tasks, income bracket, location, population density, population characteristics, culture, consumption pattern and seasons [6]. The quantity of MSW generated across cities in Nigeria is closely associated with population, economic, political and commercial activities. All these variables are however tied to the human element, as the driver of these changes. Changes in population pattern have been closely associated with changes in waste generation, even in the presence of optimally articulated management approaches. **Table 1** presented the close relationship between population and waste generation for the world's regions. It is noteworthy that regions with increasing or high per capita for MSW are the regions with high income. Nigeria had a population increase of between 2.6 and 2.7% annually between 2010 and 2018 and oscillated around 2% since 1965 [7]. The per capita income also increases steadily [1] which translated to increased purchasing power and consumptions of more products, with attendant waste generation. However, apart from Lagos State, waste generation data are not readily available or limited in coverage. The MSW per capita per day for different Nigerian cities is presented in **Table 2**, while **Figure 2** showed MSW per capita for low- (Agric), middle- (Bariga and Ojodu) and high-income (Lagos Island) locations in Lagos State over a period of 30 days. These values are comparable to the suggested per capita for the African region (**Table 1**).The data presented further extended the suggestion of a direct relationship between economic success and waste generation.

Accordingly, solid waste can be classified into four different types [13] depending on their source, which include:

a. Household waste, generally classified as municipal waste.

b. Industrial waste, as hazardous waste.

c. Biomedical waste or hospital waste, as infectious waste.

d. Electronic waste (e-waste).

Plate 1.
Selected sources and disposal of municipal solid wastes in Nigeria. (a) Waste paper, (b) Cassava peels and chaff, (c) mixed wastes, (d) waste labels, (e) waste bottles, (f) sorted wastes, (g) dumpsite in Sango-Ota(Ogun State), (h) dumpsite in Benin (Edo State), (i) Kara abattoir (Ogun State), (j) Ona River (Oyo State), (k) Mile 2 canal (Lagos State), and (l) Ikpoba River (Edo State).

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Region	Current available data			Projections for 2025			
	Total urban population (millions)	Urban waste generation		Projected population		Projected urban waste	
		Per capita (kg/capita/day)	Total (tons/day)	Total population (millions)	Urban population (millions)	Per capita (kg/capita/day)	Total (tons/day)
AFR	260	0.65	169,119	1152	518	0.85	441,840
EAP	777	0.95	738,958	2124	1229	1.5	1,865,379
ECA	227	1.1	254,389	339	239	1.5	354,810
LCR	399	1.1	437,545	681	466	1.6	728,392
MENA	162	1.1	173,545	379	257	1.43	369,320
OECD	729	2.2	1,566,286	1031	842	2.1	1,742,417
AR	426	0.45	192,410	1938	734	0.77	567,545

Source: World Bank Group [1].
AFR, Africa Region; EAP, East Asia and Pacific Region; ECA, Europe and Central Asian Region; LCR, Latin America and Caribbean Region; MENA, Middle East and North Africa Region; OECD, Organisation for Economic Co-operation and Development; SAR, South Asia Region.

Table 1.
Current and projected generation pattern for different regions of the world.

City	Kg/capita/day
Lagos	0.63
Kano	0.56
Ibadan	0.51
Kaduna	0.58
Port Harcourt	0.60
Makurdi	0.48
Onitsha	0.53
Nsukka	0.44
Abuja	0.45–0.74
Ado Ekiti	0.71
Akure	0.54
Abeokuta	0.60–0.66
Aba	0.46
Ilorin	0.43
Lafia	0.39–1.02
Gombe	0.26–0.29
Makurdi	0.37–0.62

City	Kg/capita/day
Jimeta	0.39–1.02
Gboko	0.41–0.49
Source: Refs. [8–11].	

Table 2.
Per capita wastes for Nigerian cities.

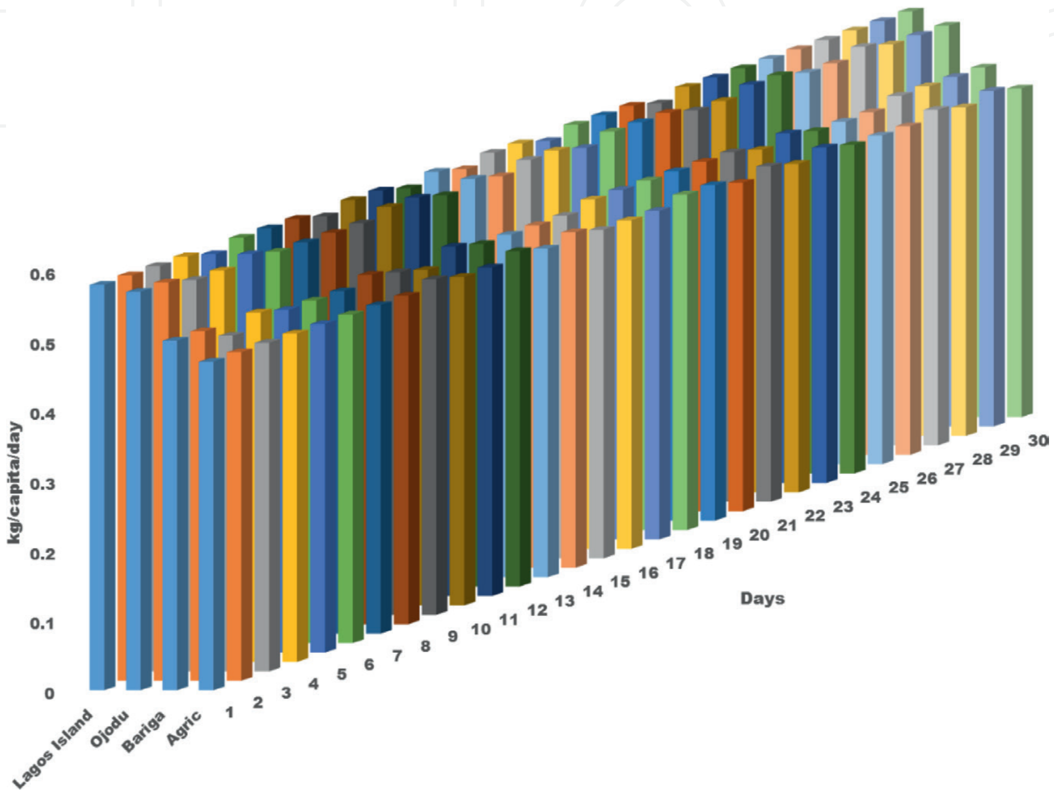

Figure 2.
Daily per capita waste generation of different incomes and densities from Lagos State, Nigeria. Modified from [12].

It is important to mention that until recently in Nigeria, MSW disposal methods (**Table 3**) received very little attention because wastes were considered an entity with homogenous properties [26, 27] or largely dominated by organic/decomposable wastes. Previous reports [28, 29] clearly supported this position and also suggested that study of wastes in Nigeria started in the 1970s. The components of MSW from different parts of Nigeria are presented in **Tables 4–8**, which showed that MSW are still largely dominated by organic/decomposable components. Shift in waste characteristics is however gradually becoming apparent reflecting changes from previously ignored traditional household electronic wastes to high-profile ubiquitous wastes of a technology-driven economy, in the form of heterogeneous components, popularly referred to as electronic wastes (e-wastes) and related components. The wastes from traditional household electronics have also increased with better purchasing power over time.

E-wastes were largely unacknowledged in Nigeria and considered part of MSW until the Koko waste incidence of 1988. This led to the separation of discarded household, ICT and personal electronic devices as e-wastes [48, 49]. The availability of cheaper versions of everyday ICT and personal electronic devices now provides additional source of consistent waste volume arising from short life cycle of substandard products. The volume and characteristics of MSW showing

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Collection methods	Aba	Abeokuta	Abuja	Akure	Akoko Edo	Gombe	Birnin Kebbi	Maiduguri	Makurdi	Yola	Ughelli	Benin
Waste collection contractor	X	X	X	X		X		X	X		X	
Deposited at waste dump	X	X	X	X	X	X	X	X	X	X	X	X
Solid to other industries/ recycling	X	X	X					X	X		X	
Deposited in the river	X	X			X							
Deposited in drainage		X		X	X	X				X		
Compositing	X		X						X		X	
Incinerating/burning	X	X	X	X	X	X	X	X	X	X	X	X
Burying	X	X	X		X			X	X	X	X	X
Open space/plot dumping		X			X	X	X	X	X	X	X	X
Government trucks		X	X	X	X			X	X		X	

Modified from [8–10, 14–25].

Table 3.
MSW disposal methods from different Nigeria cities.

Waste components	Aba	Abeokuta	Maiduguri	Gombe	Ilorin	Kano	Warri
	Abia State	**Ogun State**	**Borno State**	**Yobe State**	**Kwara State**	**Kano State**	**Delta State**
Rubber						11.30–18.50	
Plastics	6.25	24.95	18.10		23.00–27.80		2.35–4.89
Papers	9.90	25.57	7.50	22.00–26.00		3.84–23.55	0.48–4.19
Glass	4.69	5.75	4.30	20.00–24.00	12.00–26.10	2.75–20.55	4.16–10.41
Aluminum scraps	9.90					2.20–9.49	0.52–4.69
Metal scraps	10.41	5.26	9.10				27.25–31.01
Tins and cans							8.71–20.71
Ceramics							0.35–3.74
Wood							1.19–4.39
Textiles		9.48	3.90			3.80–9.30	0.39–2.84
Compostable (e.g. food and wood)	47.39		25.80				
Food waste only				28.00–32.00	24.00–30.90	4.20–31.56	
Leaves and human feces					6.50–14.10		
Vegetables						13.30–23.00	0.26–7.62
Water sachets and cellophane packages	11.45						4.99–9.08
Hazardous wastes		2.69					
Ash			21.50			1.10–22.54	
Miscellaneous/others			9.80	22.00–28.00	15.60–21.00	1.74–6.35	20.71–34.91
	[15]	[8]	[23]	[24]	[30]	[31]	[32]

Table 4.
Waste components from Nigerian cities. I.

Waste components	Kaduna	Zaria	Onitsha	Yenagoa	Yola	Jos	Gboko	Makurdi
	Kaduna State		**Anambra State**	**Bayelsa State**	**Adamawa State**	**Plateau State**	**Benue State**	
Rubber	35	36	10.1	20.7–24.6				
Plastics			17.9		18.3	6.2–7.89		
Papers			8.1	13.6–14.7		17.7–22.3	10.0–14.0	2.1–10.9
Glass			4.5	9.4–10.9	3.0	7.9–13.1	7.0–10.0	0.1–6.9
Aluminum scraps								
Metal scraps			8.7	5.7–5.9	5.8	6.3–7.5	9.0–11.0	0.7–3.4
Tins and cans								
Water sachets and cellophane packages						6.3–9.9	15.0–22.0	5.9–10.2 (+plastics)

Waste components	Kaduna	Zaria	Onitsha	Yenagoa	Yola	Jos	Gboko	Makurdi
	Kaduna State		Anambra State	Bayelsa State	Adamawa State	Plateau State	Benue State	
Ceramics								
Textiles	5	1	10.1		67.6	5.7–8.6	9.0–12.0	0.3–6.1
Wood	16	26	10.1	2.5–3.6		5.5–12.6		
Compostable (e.g. food and wood)			6.5				15.0–21.0	23.4–57.5
Food waste only			40.50	40.8–42.8		12.2–14.2		
Vegetables						13.4–15.2		
Leaves and human feces	29	19						
Hazardous wastes	20	14						
Leather						3.8–6.6		
Ash/fines				2.1–2.8			10.0–12.0	21.0–48.7
Miscellaneous/others			3.7		5.3		8.0–10.0	1.7–28.9
	[33]		[34]	[35]	[36]	[37]	[38]	[21]

Table 5.
Waste components from Nigerian cities. II.

Waste components	Abuja		
Rubber	0.2–3.4		8.1–26.7
Plastics	16.2–21.3	3.4	2.3 –13.9
Papers	6.9–13.6	25.3	3.2–13.4
Glass	4.1–5.5	3.00	0.8 –6.5
Metal scraps	3.3–6.7	3.14	1.0–7.9
Tins and cans			
Ceramics			0.1–8.8
Textiles	0.1–4.7	3.0	0.2–4.8
Compostable (e.g. food and wood)		42.6	44.1–65.1
Food waste only	52.0–65.3		
Leaves and human feces			
Vegetables			
Water sachets and cellophane packages		14.5	7.8–18.6
Hazardous wastes		2.8	1.1–5.5
Ash			1.0–10.7
Miscellaneous/others	0.6–2.8	2.2	0.9–11.2
	[10, 25]	[16]	[39]

Table 6.
Waste components from Abuja.

Waste components	Lagos				
Plastics	7.29	3.6	5.0	15	6
Papers	10.2	12.5	10.0	10	6
Glass	2.8	1.8	2.0	5	8
Aluminum scraps					
Metal scraps	4.1	2.1	3.0	5	10
Water sachets and cellophane packages		7.7	9.0		
Textiles	3.8		5.0	4	6
Compostable (e.g. food and wood)	29.8	68.2		8	8
Food waste only			66.0		
Leaves and human feces					
Vegetables				45	50
Bones	1.8				
Ash/fines	21.2	4.2		8	10
Miscellaneous/others	18.8				
	[40]	[41]	[12]	[42]	[43]

Table 7.
Waste components from Lagos State.

Waste components	Port Harcourt				
Rubber					7.6
Plastics	1.5–8.3	2.2–4.8	11.5	18.0	9.9
Papers	4.0–16.5	5.6–16.5	12.3	24.2	12.4
Glass	0.2–6.3	0.2–2.5	9.5	10.9	13.5
Metal scraps	0.5–15.0	0.5–4.0	15.2		17.2
Tins and cans				10.9	
Water sachets and cellophane packages	9.9–18.5	10.5–14.7			
Textiles					7.6
Wood				18.0	8.4
Compostable (e.g. food and wood)	52.1–69.0	60.0–69.0	51.5		
Food waste only					29.2
Leaves and human feces					
Vegetables				18.0	
Miscellaneous/others	2.0–8.1	2.0–6.8			1.8
	[11]	[44]	[45]	[46]	[47]

Table 8.
Waste components from Port Harcourt.

e-waste proportion from dumpsites or landfills were absent from available studies. The isolation of e-waste as a unique recent component, activities of scavengers or pickers, electronic market dumpsites and dedicated studies to e-wastes probably contributed to the lack of such data.

3. Municipal solid waste and inland water bodies in Nigeria

The magnitude of changes experienced by inland water bodies as a result of MSW in Nigeria could be attributed to inappropriate siting, design, operation and maintenance of dumps and landfills. The history of the association between changes in quality of inland waters and MSW generation in Nigeria has not been adequately documented. However, classical reports [50, 51] provided a different trajectory to the narratives, where low-level perturbations reported for both the Ona River and Ogunpa River were associated with generation and disposal of MSW in Ibadan, Southwest Nigeria. Inland waters in Nigeria have been on the receiving end of MSW, but the details have been patchy. Inland surface and groundwaters in the vicinity of dumpsites in Nigeria have been reported to be generally compromised, and leachates have been the most cited reason.

Dumpsites usually undergo modification of wastes [52] in the following five basic steps:

- Phase I (lag phase/initial adjustment).
- Phase II (transition phase).
- Phase III (acid formation phase).
- Phase IV (methane production/fermentation phase/methanogenic phase).
- Phase V (maturation phase).

The products of these processes include volatilized chemicals as gas, leachate and changing community of organisms, all of which have profound influence on the physical, chemical and biological conditions in the immediate surroundings.

Leachates from dumpsites and landfills have been characterized (**Table 9**) and associated with contamination of inland surface water (**Table 10**) and groundwater (**Table 11**) resources from different parts of Nigeria with profound physical, chemical and biological consequences. Aquatic life and recreational criteria [53] suggested compromise in physical and chemical qualities, due largely to the presence of dumpsites close to these water bodies. Also age and the unique composition or characteristics of wastes deposited at dumpsites will greatly influence the resultant water quality. The biotic or biological responses of resident organisms to changes as elicited by activities associated with dumpsites have not attracted deserved attention or investigation considering the ecological and public health consequences. However, limited laboratory studies on aquatic organisms, *Chironomus* sp. *Culex pipiens*, *Bufo regularis* tadpoles and *Clarias gariepinus*, using products from dumpsites in the form of leachates from Oyo [57, 58, 77] and Lagos [77, 78] States showed pronounced aberrant behavioral responses and gross morphological and genetic damages. In spite of the limited studies from Nigeria, the reports agreed with comparable reports from other parts of the world on the negative influence of products of dumpsites on surface inland waters.

Groundwater in Nigeria provides water supply for 40.1% of Nigerians [79] and is considered to be the preferred source of water for different sectors providing about 40% of water public water supply [80] underlying the importance of groundwater sources. The integrity of such groundwater is therefore of importance because of direct consequences on human health. The quality of groundwater showed the presence of substances considered dangerous to human health at concentrations above standards [53, 68] considered acceptable. The detection of cadmium, nickel,

Parameters	National criteria	Odo Oba (Osun State)	Aba Eku (Oyo State)		Olusosun (Lagos State)		Aba Eku	Olusosun	Aba Eku
			Raw	Simulated	Raw	Simulated			
pH	6.5–8.5	6.25	8.6	4.9–5.5	7.30	6.80	7.8	8.1	8.0–8.3
Color		Dark brown					Dark brown	Dark brown	
TS		5072.17	3054.50	3281.00–4206.00			3116.67	4100.3	433–2091
TSS	0.75		1085.00	220.00–2490.00					1–460
TDS		3400	1969.50	1716.00–3412.00	0.32	1.32			
Total hardness		259.36			540		532	615	
Chloride		30	42.00	34–38	770.00	240.00	1106	1099	149–4280.0
BOD	6.0		3.67	2.99–3.83	598.00	590.00	601	594	110.7
COD	30.0		5.50	4.50–5.78	480.00	370.00	512	487	29–338.2
Turbidity			1030.00	440–1875					
Phosphate	3.5		895	175.5–450.73			122.02	215.7	ND
Nitrate	40.0		97.94	24.92–170.84	3.86	2.46	54.4	72.3	38.6–95.1
Sulphide			1.21	0.29–2.28					
Sulphate	500		102.5	101.05–122.10	68.58	48.20	114.34	218.12	10–252
Ammonia	0.08		47.34	41.48–95.16	0.86	78.68	86.4	122.1	83.9
Ammonium	2.0								0.1–7.0
Alkalinity					480.00	300.00	502	623	
Calcium	180		2570.00	2500.00–3751.40					30–182
Potassium	120		1800.00	1340.00–2250.00					
Sodium	50		79.20	126.50–7740.00					
Mg	40		2.40	4.00–12.00					18–175

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Parameters	National criteria	Odo Oba (Osun State)	Aba Eku (Oyo State)		Olusosun (Lagos State)		Aba Eku	Olusosun	Aba Eku
			Raw	Simulated	Raw	Simulated			
Cu	0.01	0.0935	4.50	5.30–20.00	0.77	0.44	2.44	3.86	ND–0.103
Pb	0.1	0.0588	2.20	3.60–8.80	1.40	0.69	2.08	2.00	0.008–73.3
Fe	0.5	8.321			1.90	0.83	3.20	4.71	0.30–50.5
Cd	0.01	0.0385	2.20	3.65–8.82	0.58	0.46	1.44	2.20	0.4–5.7
Ag		0.0163							
Mn		0.253	2.80	4.20–15.00	0.79	0.46	2.90	3.10	0.6–23.8
Ni	0.1	0.249	3.60	1.80–5.12			1.88	2.51	ND–0.10
Ar			2.26	3.63–8.83					
Zn	0.2		3.60	5.00–18.00					0.3–3.5
Hg	0.0005		2.38	2.14–8.75	0.41	0.23			
Cr	0.5		2.28	2.50–8.70			2.32	2.43	0.04–2.5
As					0.36	0.27	1.50	2.60	
	[53]	[110]	[54]		[55]		[56]		[57, 58]

All in mg/l except pH and colour.

Table 9.
Leachate characteristics from dumpsites and landfills from Southwest Nigeria.

Parameters	**National criteria**	**Effurun**	**Nnewi**	**Agbani**	**Abakaliki**	**Onitsha**	**Aba**	**Akoko Edo**	**Ibadan (Ona River)**	
									2002	**1997**
		Delta State	**Anambra State**	**Enugu**	**Ebonyi**	**Anambra**	**Abia**	**Ondo**	**Oyo State**	
EC		628.0–694.5	140.3–197.0				18.6–790.2	43.4–48.60	366–611	160–600
TDS		80.3–694.5	12.28–16.82	10.0–30.0			10.3–855.8	320–364	408–2054	90–250
Total solids			16.81–21.7	40.0–380.0			80.0–81.7	535.0–600.0	460–2160	
Turbidity			180.0–338.54				0.04–32.1	3.62–5.91		
TSS	0.25							171–265	38–170	
Ca^{2+}	180	8.0–39.0		1.60–28.10			13.3–158.2		ND–4.0	
Mg^{2+}	40	12.0–214.0		ND–97.30			4.60–10.00			
Fe^{2+}	0.05	0.08–1.82		0.17–1.89		0.10–0.80	19.61–32.14			0.03–0.6
Na^{2+}	120	65.89–118.72							184–358	
K^{2+}	50	45.91–49.19							2.0–8.0	
Nitrate	9.1	0.87–1.25		0.22–2.43			0.20–8.20	8.04–8.28		
Phosphate	3.5	3.60–50.34	6.13–7.25				0.20–10.40	1.39–1.41	700.0–1129	
Sulphate	100	64.0–100.5	211.66–239.17				27.4–103.8	63.0–74.0	386–480	
Chloride	300	40.5–240.6	122.93–164.82	2.00–47.90			12.1–184.0	143–190	45.0–70.0	
Alkalinity			24.97–33.87				3.1–3.3			40.9–175.8
Acidity							2.0			
Ammonia-nitrogen										ND–2.2
Ammonium	0.05	1.02–3.24								
Total hardness				4.0–40.0			18.1–168.2		129–320	
%TOC							2.98–3.01			

Parameters	National criteria	Effurun	Nnewi	Agbani	Abakaliki	Onitsha	Aba	Akoko Edo	Ibadan (Ona River)	
									2002	1997
		Delta State	Anambra State	Enugu	Ebonyi	Anambra	Abia	Ondo	Oyo State	
Phenol									1.2–2.0	
pH	6.5–8.5	6.8–7.0	6.77–6.97	3.5–6.0			6.1–6.8	6.43–7.24		7.2–8.9
DO	>6.0		43.04–63.93	1.4–4.9			5.6–11.3			0.9 –22.1
BOD	3.0	6.8–8.9	12.67–20.55	5.0–18.0			3.8–37.9			0.00–11.4
COD	30.0	55.0–95.0	264.89–342.45	60.0–320.0			5.6–53.0			
Zinc	0.01		0.40–1.42		0.14–0.16	0.30–1.30	0.48–0.57		2.10–2.5	0.007–0.5
Aluminum	0.2								23–76	
Copper	0.001		0.40–0.08		0.9–1.0	010–0.90	0.001			ND
Chromium	0.001				0.02–0.04		0.001		3.0–4.0	ND–0.03
Cadmium	0.005				0.02–0.05	0.22–0.99	0.001		ND–2.50	ND–0.01
Iron	0.05		1.46–6.42						17–25	
Lead	0.01		0.23–0.31		0.06–0.08	0.11–1.99	0.06–0.09		32–51	ND–0.06
Nickel	0.01						0.053–0.06			
Arsenate	0.05					0.21–2.6				
Mercury	0.001					0.3–1.8				
Cobalt										0.02–0.2
Manganese										0.01–0.17
	[53]	[59]	[60]	[61]	[62]	[2]	[63, 64]	[65]	[66]	[67]

Table 10.
Quality of inland surface waters receiving dumpsite/landfill effluent/products from Nigerian cities.

Parameters	National criteria		Abuja	Ilokun	Effurun	Minna	Onitsha	Ota	Akoko Edo	Lagos	Ibadan	
										Olusosun/ Ojota	Ring road	Aba Eku
				Ekiti State	Delta State	Niger State	Anambra State	Ogun State	Ondo State	Lagos State	Oyo State	
Electrical conductivity (μS/cm)		1000.0	30–213		20.3–1200.0	344.0–1191.0		15–1572	13.6–51.8	107.0–4043.0	172–868	106.9–696.0
Total dissolved solids(mg/l)		500.0	65–132		9.7–765.4	210.0–738.9		8–836	102.0–415.0	40.0–2021.0	147–1100	53.9–347.0
Suspended solids (mg/l)			15–35						13.0–52.0		14.0–85.0	0.00–246.0
Total solids	1500.0								115.0–430.0	500.0–1370.0	160–1620	53.4–347.0
Turbidity (NTU)		5	1–9			4.5–38.7			1.2–2.3			
Phenol	2.0	0.001									0.20–1.0	
pH	6.5–9.2	6.5–8.5	6.8–7.2		6.3–7.1	7.2–8.4		4.5–6.01	5.8–7.0	3.8–7.0	5.56–8.22	7.4–8.3
Fe	1.0	0.3	ND–0.32	0.12–0.5	0.001–1.9		0.5–2.91	2.4–4.5		0.06–5.5	ND–21	ND–16.9
Mg	150.0	20.0		3.5–5.2	0.1–1.5		ND–18.72	1.5–13.1		4.6–74.9		1.6–84.9
Zn	15	3.0		0.2–0.4			0.18–0.60	2.0–3.1		1.01–2.7	0.9–3.6	ND–2.5
Mn	0.5	0.2		0.1–0.3			ND–0.55	0.7–0.9		0.03–1.3		ND–0.5
K					5.8–32.2			2.1–2.9		1.0–4.1	0.6–2.5	0.9–52.4
Na		200.0			10.7–65.4			5.8–7.1		4.0–13.4	104–292	
Ca	200			29.1–72.1	11.3–38.0	71.0–327.0		4.0–89.9		4.0–98.2	1.0–9.0	3.7–87.5

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Parameters	National criteria		Abuja	Ilokun	Effurun	Minna	Onitsha	Ota	Akoko Edo	Lagos	Ibadan	
										Olusosun/ Ojota	Ring road	Aba Eku
				Ekiti State	Delta State	Niger State	Anambra State	Ogun State	Ondo State	Lagos State	Oyo State	
Cd	0.006	0.003		ND–0.001			0.22–0.24			0.004–0.007	ND–3.6	0.01–0.2
Ni	0.075			ND–0.007			ND–0.03	0.01–0.03		0.02–0.03		ND–0.22
Cr	0.03	0.05		0.007–0.01			ND–0.002	0.01–0.03		0.009–0.12	1.0–6.0	ND–0.05
Cu	0.075	1.0		0.02–0.4			0.03–0.2	0.29–0.67		0.04–0.6		ND–0.04
Pb	0.075	0.01		0.001–0.03			0.19–0.5	ND–0.03		0.003–0.08	ND–58	ND–0.2
As	0.06	0.01		0.001–0.001			0.003–0.5					
Silver							ND–0.02					
Aluminum		0.2					ND–0.007				19–42	
Molybdenum							ND–0.9					
Mercury	0.0003	0.001					0.002–0.4					
Cobalt	0.1						ND–0.081			0.025–0.001		
Cl	600	250.0		39.6–216.7	8.9–225.0	28.1–167.9		70.9–186.5	126.0–304.0	53.1–726.0	20.00–118.00	1.5–68.9
Sulphate	400	100.0	20–231	2.6–6.2	ND–24.3			11–278	54.0–130.0	2.0–735.0	114–700	1.6–43.2
Nitrate (N)	50	50.0	3.6–8.0		0.08–56.0			1.3–16.7	4.4–8.8	ND–45.0		0.1–44.2
NO_3			0.2–41.5	0.02–0.2						9.3–66.0		

Parameters	National criteria		Abuja	Ilokun	Effurun	Minna	Onitsha	Ota	Akoko Edo	Lagos	Ibadan	
										Olusosun/ Ojota	Ring road	Aba Eku
				Ekiti State	Delta State	Niger State	Anambra State	Ogun State	Ondo State	Lagos State	Oyo State	
Nitrite	2	0.2		ND		0.001–0.2				0.06–0.98		
Ammonium					ND–0.9					0.16–96.0		0.03–0.7
Total hardness			19.4–79.0			112.0–444.0		10–212		45.0–367.0	78.8–428	
Hardness (Ca) $CaCO_3$	500	150.0	28.7–48.7									
Hardness (Mg) $CaCO_3$			28.7–48.7									
Total alkalinity (mg/l)			4.00–74.0									
Phosphate as phosphorus			0.01–0.2	ND–0.3	ND–8.3	0.3–0.9		10.3–42.	0.4–0.9	0.02–40.8	257–1040	
BOD					ND–16.4	4.1–8.1				40.0–3427.0		
COD					ND–35.0					1.8–3170.0		4.2–18.7
DO						3.6–9.5				0.5–0.7		
	[53]	[68]	[69]	[70]	[59]	[71]	[2, 72]	[73]	[64]	[72, 74, 75]	[66]	[76]

Table 11.
Quality of inland groundwaters receiving dumpsite/landfill effluent/products from Nigerian cities.

chromium, copper, lead, arsenic and aluminum and cobalt in groundwater from most locations should be a cause for concern and perhaps necessitates detailed nationwide surveillance, considering the proportion of population dependent on groundwater. The intake of these metals has been implicated in a variety of human ailments leading to severe problems via disruption of metabolic functions in two ways [81]:

1. They accumulate and thereby disrupt function in vital organs and glands such as the heart, brain, kidneys, bone, liver, etc.

2. They displace the vital nutritional minerals from their original place, thereby hindering their biological function.

Residents around the dumpsites are partly or wholly dependent largely on either surface or groundwater for direct or indirect daily water requirements. Thus contact with these water bodies is inevitable, even at distances considered areas with no likely effects. Determination of the health implications of such contacts at present has not been clearly defined, from very limited reports on public health aspects of dumpsite managements. This is because it has not been possible to separate consequences of dumpsite contaminated surface and groundwater contacts from medical conditions associated with population living around dumpsites. Studies [82–85] reported the following: inhalation of odor, exposure to dust, exposure to smoke, exposure through water sources, consumption of plant materials, consumption of animal materials, exposure through organisms (vectors), noise from vehicles, exposure to fire, dermal contacts and exposure through domestic animals as possible routes of human exposure and contact with dumpsites and products of dumpsite modifications. Medical conditions reported from the population living close to dumpsites in different parts of Nigeria are presented in **Table 12**, which have been observed in Nigeria from areas of regular contacts with contaminated water [90] but not from dumpsites or landfills. The implication of the above is that symptoms may indicate conditions from multiple exposures or contacts. Inland waters in Nigeria have been subjected to inundations with inputs from multiple sources with resultant changes in quality. The almost hidden nature of contamination and contamination routes by dumpsites reinforces the dangers of not paying required attention to dumpsites, associated activities and value chain. This is because each step or link has an effect on inland water and hence human population making these sources of contamination very dangerous and harmful. Therefore, numerous health hazards associated with waste dump sites in major economic centres in Nigeria [27, 91, 92] can be said to be largely denominated by the resident and/or dominant waste components.

Radionuclides have also been reported and associated with dumpsites and landfills in Lagos State [93–95], Oyo State [95–97], Ogun State [98–100], Plateau State [101], Benue State [101], Ekiti State [95], Rivers State [102–105] and Delta State [106]. These dangerous natural and artificial radiation materials from unregulated and unmanaged dumpsites and landfills released into inland water sources pose risks to resident organisms and population of humans, dependent directly on water for domestic purpose and consumption of resident aquatic organisms.

Radionuclides have been reported in leachates [102] and groundwater [102, 105, 107] and rivers [107, 108] with identified sources being the human activities, inclusive of dumpsites [102, 105] and abattoir wastes [109]. Dumpsites and landfills are therefore potential sources of radionuclide inputs into inland surface

Lagos	Port Harcourt/Owerri/Aba
Asthma	High temperature and fever/typhoid
Bronchitis	Watery stool/frequent stooling
Chest pain	Vomiting
Lung disease	Catarrh and cough
Nose/throat problems	Loss of appetite
Breathing	Pains in the abdomen and body
Tuberculosis	Dizziness
Skin infection	Blood spotted stool
Headaches/nausea/diarrhea/dysentery	Urinary tract infection
Children's diseases	Acute osteomyelitis
Accident/injury	
Malaria	
[84, 86, 87]	[88, 89]

Table 12.
Ailments associated with population living near dumpsites.

and groundwaters; the above-cited reports indicated the presence of radionuclides in soils around target dumpsites, confirming the migration of substances from dumpsites, as reported [108], using time-lapsed vertical electrical sounding (VES). This migration of materials into ground- and surface waters will facilitate exposure of resident and non-resident population to radioactive material by direct or indirect intake, respectively. Low cancer risks from chronic exposure to radiation from dumpsites in Nigeria have been suggested [97] even at the low level, thus further establishing the need for urgent management strategies for MSW in Nigeria.

4. Conclusion and recommendation

Nigeria's development is currently enjoying active support of multilateral agencies, with the sole aim of expanding and diversifying the economy through, but not limited to, multinational manufacturing and small- and medium-scale enterprises. These are desirable and needed to improve socioeconomic status of the populace. However, complementary in-depth consideration of the ecological consequences of expanded economy must include increased generation of MSW, which usually begin with unregulated and undocumented dumpsites associated with penetration of economic activities. The inability of agencies responsible for waste management to anticipate and plan for the increase of MSW is the major reason for the surge in MSW generation and persistence. These will eventually become sources of sometime unexplained inland water contamination and/or public health problems or outbreaks. In view of this, the following be deeply considered to minimize the negative impacts of MSW on inland waters:

1. Collection of dumpsite and landfill history and location data in each local government area (LGA) nationwide.

2. Characterize wastes associated with each dumpsite and landfill, to provide data for risk assessment of dumpsite or landfill products.

3. Information on nearby surface and groundwater and their utilization by residents.

4. Information on geophysical assessment of pollutant movements in soil.

5. Regular determination of inland water quality in the vicinity.

6. Create awareness on the need to sort waste from source before disposal.

7. Encourage adoption of recycle and reuse of wastes to reduce wastes generated.

8. Undertake spatial analyses of population or residents' socioeconomic characteristics to predict waste profiles and determine appropriate management MSW strategy.

Conflict of interest

I declared no conflict of interest.

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