

# Healthcare Waste Management in Nigeria: A Review

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**Abstract:** Healthcare waste management has become an important aspect of medical care delivery globally. This is simply because of its hazardous and infectious components that have greater potential for adverse health and environmental impacts. As such, certain guidelines and procedures have been developed by international aid agencies and conventions to guide national governments and local administrations in formulating policies and practices for effective healthcare waste management. In this work, we reviewed the existing literature to appraise the status of healthcare waste management practices in Nigeria. This included generation, segregation, collection, storage, transportation, treatment, and disposal. The current work further reviewed the other essential elements of healthcare waste management, such as policy landscapes, training, awareness, and waste characterization, and discusses challenges and opportunities for effective healthcare waste management in Nigeria. Among the challenges are poor funding, inadequate training, ineffective legislature, and absence of data. However, there are available low-cost technologies that are suitable for the treatment of waste in a developing country like Nigeria. This technology variant offers an opportunity for a circular economy as it can simultaneously achieve energy production, waste management, and other socioeconomic advantages.

**Keywords:** healthcare waste; medical waste; hospital waste; circular economy; Nigeria; waste management

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## 1. Introduction

Healthcare waste, also known as medical waste or biomedical waste, is defined as all forms of waste arising from activities within health care facilities, research centers, and laboratories related to medical procedures [1]. In a typical healthcare facility, about 75% to 90% of the generated waste is usually nonhazardous and classified as general solid waste, while the remaining 10% to 25% is hazardous [2]. These hazardous components pose a great risk to public health and could undermine environmental sustainability if not properly handled. Examples of hazardous waste categories found in healthcare facilities include sharp waste, infectious waste, pathological waste, pharmaceutical waste, cytotoxic waste, chemical waste, and radioactive waste. This simply indicates that healthcare waste is a mix of both hazardous and nonhazardous waste streams, thereby requiring a specialized method of handling through the stages of collection, segregation, storage, transportation, disposal, treatment, and recycling. Other essential elements of healthcare waste management such as waste minimization, policy guidelines, waste management planning, waste management training, etc., also require specialized modalities to ensure effective outcomes.

In general, the management of healthcare waste is still a huge challenge in low- and middle-income countries because of some reasons. These include but are not limited to

poor awareness of the health hazards associated with this variant of waste, inadequate training in proper waste management techniques, inadequate or absence of state-of-the-art waste management, and disposal facilities, unavailability of economic resources, and low-priority attention given to the issue [3–6]. However, following the heightening global awareness of the adverse health, environmental, and socioeconomic impact linked to poorly managed healthcare waste, especially in the advent of COVID-19, several nations are making a concerted effort in managing their healthcare waste [7]. Most of these efforts are in the form of active government intervention through national policies whereby the responsible government ministry describes the changes needed in the national healthcare policies, the roles of healthcare staff and other parties, and the method of policy enforcement. The national policy often follows the international best practices and guidelines as laid down by the World Health Organization, International Solid Waste Association, the Basel Convention, and other international agreements and conventions. One important outcome of the recent global concern on the effective management of healthcare waste is that it is generally accepted that medical waste management has become an inseparable component of healthcare delivery [8,9]. This simply implies that planning healthcare delivery activities should also incorporate procedures for effective management of the anticipated waste to be generated.

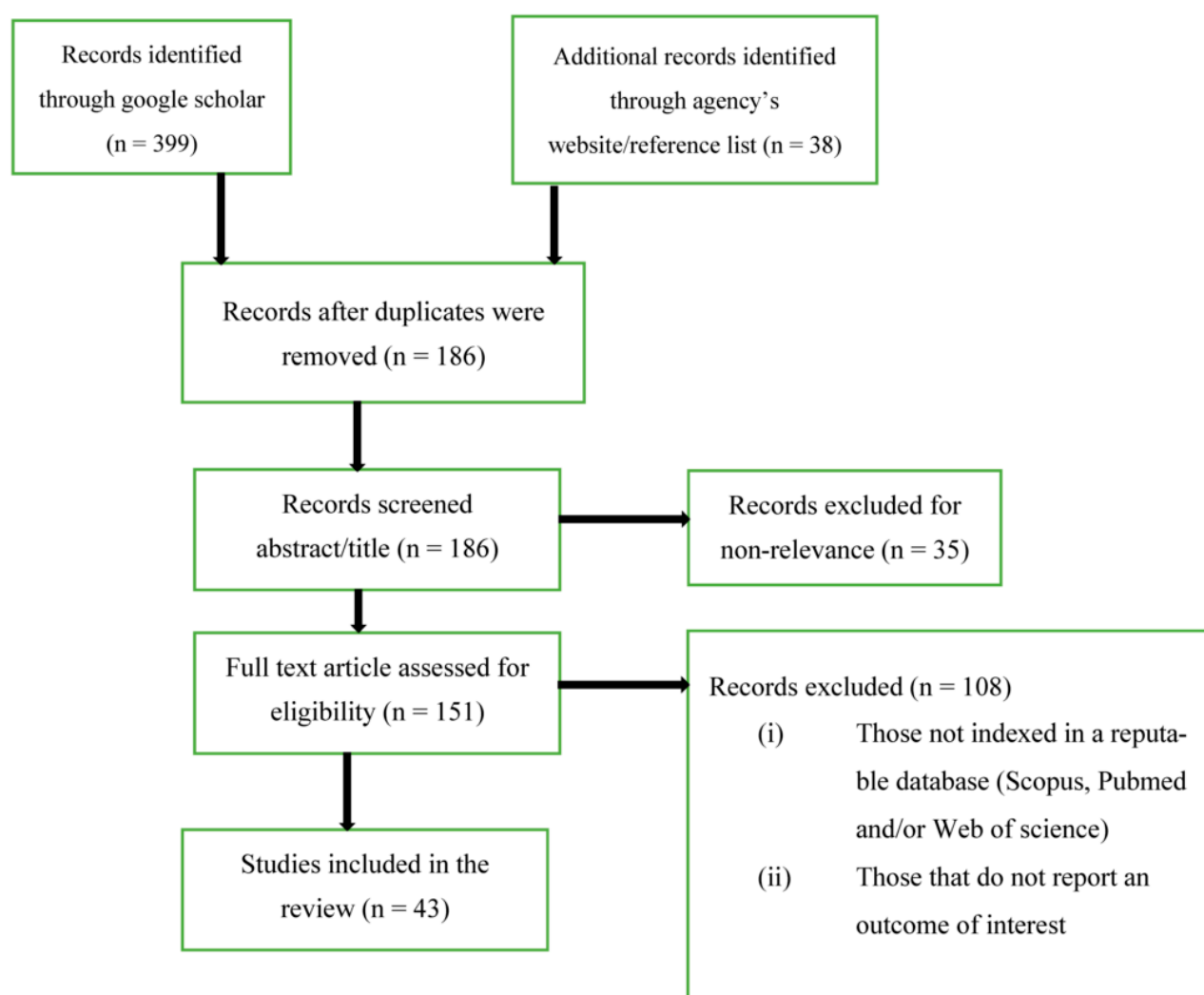
In Nigeria, municipal solid waste management has not received satisfactory attention due to the limited economic resources, poor policy regimes, inadequate public infrastructure, and the absence of other critical capacities [10]. As a result of inadequate economic resources, health-related issues compete with other sectors of the economy for limited available resources [5]. This work aims to appraise the existing practices, policies, and other general developments in healthcare waste management in Nigeria and also discuss the challenges and opportunities for the adoption of sustainable measures in the effective management of healthcare waste. The importance of this work is further premised on the opinion that quality improvement is an iterative process that often requires some trial and error, but due to the hazardous nature of healthcare waste that gives limited room for experimentation, a careful study of the prevailing local conditions is essential before any waste management improvement plan is established [6].

## 2. Materials and Methods

We conducted a focused literature search on Google Scholar (the most comprehensive research database) to identify the relevant literature on healthcare waste management in Nigeria. We also searched for other relevant gray publications such as national and international agencies' publications, international conferences, convention guidelines, policy briefs, and project documents of agencies. We also included relevant documents identified from the reference list of the selected materials. The keywords for the search included "healthcare waste management," "hospital waste management," "medical waste management," "hazardous waste management," "biomedical waste management," and "infectious waste management." All search terms were conducted with the inclusion of the phrase "in Nigeria." Retrieved records from the search were exported to Microsoft word for screening/selection. Two of the authors participated in the document screening of the records, while another two authors independently examined the selection process to resolve disagreements and ensure consistency. Duplicate records and irrelevant materials were first removed from the study, while at the second stage of the screening, records were removed based on the following criteria: (i) Those that did not report an outcome of interest in any of the components of healthcare waste management, such as collection, characterization, sorting, disposal, policy, training and planning. (ii) Only materials published in the English language were included in the study. (iii) We also expunged articles from journals not indexed in a reputable database such as Scopus, PubMed, and/or Web of Science to avoid including predatory material. The process of literature selection/review and the number of records considered at each stage is shown in the PRISMA flowchart in Figure 1, while the list of material included/considered in the

study is included as Supplementary Material. The materials selected for the study were pre-reviewed, analyzed, and categorized to answer the following questions;

- (i) What are the motivations for rising global concern on healthcare waste management?
- (ii) What are the composition/characteristics of healthcare waste generated in Nigeria?
- (iii) What is the status of healthcare waste management practices in Nigeria in terms of collection, storage, segregation/sorting, transportation, treatment, and disposal?
- (iv) What are the healthcare waste management policy landscapes, financing mechanisms, and institutional arrangements in Nigeria?
- (v) What are the prospects and challenges for the implementation of sustainable measures in healthcare waste management in Nigeria?



**Figure 1.** PRISMA flowchart for record screening/selection.

### 3. Results

#### *Motivations for Rising Global Concern over Healthcare Waste Management*

Medical service delivery is among the essential responsibilities of national governments. Adequate healthcare delivery prevents deaths and ensures good health for the citizens and indirectly fosters an increase in their economic productivity that in turn will impact the country's gross domestic product (GDP) [11]. Notwithstanding, progressive efforts toward improving healthcare delivery will consequently increase the amount of healthcare waste generated. This increase comes as a result of the following: (i) the crea-

tion of multiple medical/healthcare facilities where variants of healthcare/biomedical activities take place such as hospitals, medical clinics, dispensaries, healthcare camps, medical outreach programs, biomedical laboratories, medical research centers, mortuary and autopsy centers and so on [12,13] and (ii) the increase in the use of disposable medical products [14].

Poorly managed healthcare waste will adversely affect public health and environmental quality in specific areas of patients' health, occupational health, and safety of the healthcare workers, injury to illegal scavengers/waste pickers, and roaming animals [15]. Other potential health hazards may include drug-resistant microorganisms that could spread from the hospital into the environment, exposure to toxic pharmaceutical products, and, chemical burns [2]. Potential environmental hazards include air pollution in form of particulate matter released during medical waste incineration or burning. Improper use of older incinerators (with little or no emission control) for healthcare waste treatment leads to the release of dioxins and furans into the environment. Underground water sources can also be polluted by burying and/or landfilling toxic healthcare waste [16].

A simple mass action model developed in 1999 by World Health Organization (WHO) indicates that annually, there are approximately 8–16 million new cases of hepatitis B virus, 2.3–4.7 million cases of hepatitis C virus, and 80,000 to 160,000 cases of HIV resulting from unsafe injections [17]. The chief culprit of these anomalies is the indiscriminate practices that occur in absence of a proper and operational healthcare waste management system. This is partly the impetus for the rising global advocacy of effective and safe healthcare waste management. Responding to these challenges, WHO in collaboration with European Center for Environment and Health set up a working committee to produce a practical guide to address healthcare waste management in developing countries. The manual published in 1999, provided directives for the responsible national and local governments on the best methods of healthcare waste management. With the assistance of the International Solid Waste Association (ISWA), a Teacher's Guide was produced for training purposes, especially for low- and middle-income countries [16].

Nevertheless, as of 2009, there were still emerging reports of public health threats across the world caused by failure or improper healthcare waste handling systems [18]. For instance, about 240 people contracted hepatitis B in India, in 2009 as a result of medical care rendered with previously used syringes acquired through a black market [19]. Also, in 2008, the healthcare waste emanating from the mass vaccination of 1.6 million people in Kabul, Afghanistan was disposed of along with the general municipal solid waste. The disposed waste was later reported to have caused significant infectious injuries to landfill scavengers [20]. The ensuing investigation rightly shows that Afghanistan lacks regulations governing safe healthcare waste management and that more than 60 hospitals in Kabul do not have incineration capacity or access to other essential healthcare waste management infrastructure [18]. Following these reports, WHO released an updated version of healthcare waste management guidelines in 2014 with more stringent measures for improving healthcare waste management across the globe. Besides, as part of monitoring Sustainable Development Goal 6 on safely managed water and sanitation, the WHO/UNICEF Joint Monitoring program will regularly report on the safe management of healthcare waste as part of wider monitoring efforts on water and sanitation in healthcare facilities [2].

According to the World Health Organization (WHO)'s guidelines, safe disposal of healthcare waste occurs at four stages, which include (i) segregation, (ii) collection and storage (iii) treatment, transportation, and (iv) safe disposal [1].

#### **4. Characterization/Composition of Healthcare Waste Generated in Nigeria**

The knowledge of the physicochemical composition of healthcare waste is essential in developing a waste minimization plan. Setting up an efficient recycling scheme will

require information on the waste composition of the nonhazardous components of the healthcare waste, while the knowledge of the physicochemical parameters of the infectious waste stream is equally needed in establishing equipment specifications and/or operating parameters for treatment technologies. For instance, some waste treatment options based on steam and microwave simply rely on the minimum amount of moisture to be present in waste material, since chemical systems are influenced by the organic load and water content. Another example is that the physical properties of the waste—bulk density (uncompacted mass per volume)—is essential in the planning of storage, transport, and perhaps the waste treatment chamber capacities, etc. Due to the heterogeneous characterizing features of societies and cities in terms of social, economic, and cultural, the composition and the physicochemical characteristics of waste generated in healthcare facilities will vary from place to place.

There are no available nationally documented data on healthcare waste characterization in Nigeria, both in the past and present. But there are several case studies of Nigerian locations [21–25]. Analysis of the available reviews shows that among the non-hazardous component of the healthcare waste generated in Nigeria, the organic component (mainly food waste) dominates, while among the hazardous component, the infectious waste (e.g. gauze, cotton wool, diaper, etc) are more [22]. There are no generally documented data on the quantity of hazardous waste available on healthcare waste generated in Nigeria; however, characterization of healthcare waste sampled at the hospitals in Abuja, the capital city of Nigeria, reported 26.5% of waste generated from healthcare facilities to be hazardous [26]. A similar result was reported in Pakistan, a developing country where 73.85% of the generated medical waste is nonhazardous [27].

## 5. Healthcare Waste Management Practices in Nigeria

### 5.1. Waste Generation

Information on waste generation is vital in planning its management. It provides prior knowledge of the anticipated quantity of waste, which will in turn help in determining the needed capacity for containers, storage areas, transportation, and treatment technologies [1]. The amount of waste generated in hospitals depends on several factors, which include the number of beds, the number of patients, the type of healthcare facility, the waste management plan, and the level of activities in different sections [24]. A previous review study on hospital waste management in developing countries reported a waste generation rate of 0.57 kg/bed/day for Nigeria [6]. Coker et al. (1999) reported that the waste generation rate in Nigeria ranges from 13 g/head/day to 632.5 g/head/day while Odewumi and Onyemkpa (2013), reported a waste generation rate of 49.6 g/head/day. The lower values for medical waste reported in Nigeria compared to other developing countries can be cogently explained by the culture of concealment and self-disposal by patients and relatives [28]. Several studies have documented varying healthcare waste generation rates for locations across Nigeria, as shown in Table 1. However, there are still disparities in the methods of studying healthcare waste generation rates among scholars. Commonly reported metrics include kg/patient/day [29,30]; kg/day [28,31]; kg/person/day [32], g/head/day [21], kg/head/day [33] and kg/ward/day [23]. In Nigeria, there are higher healthcare waste generation rates in private hospitals than in public (government-owned) hospitals [34]. The explanation is that private hospitals are mostly patronized by middle-class and high-income citizens since they can afford the high-cost charges compared with the public hospitals where medical services are substantially free with minimal charges payable [21,22]. Again, healthcare waste generated in private hospitals contains more hazardous components than in public (government-owned) hospitals. The explanation is that Nigeria has more private-owned hospitals than public hospitals.

However, the current review reveals that Lagos state has witnessed a reduction in the quantity of healthcare waste generated over time. For example, the study conducted

in 2006 in Lagos recorded a generation rate of 0.573 kg/bed/day [35] while a subsequent study conducted in 2016 recorded a generation rate of 0.181 kg/bed/day [5]. The decrease in the quantity of waste generated is probably a result of several intervention actions of the Lagos state government, through the awareness and training programs organized by Lagos State Waste Management Authority (LAWMA) medical unit. The intervention has led to improvement in the segregation of infectious waste from general waste, adequate categorization, and disposal of waste [5].

**Table 1.** Healthcare waste generation rates for locations across Nigeria.

City.	Type/Size of Facilities					The Number of Facilities Studied	Waste Generation Rate				References
	Tertiary	Secondary	Primary	Private	Public		kg/bed /day	kg/Person /Day	kg/Head /Day	kg/Ward/ Day	
Lagos	1	1				2	0.01–3.98			-	[28]
Edo	1					1	0.81	0.62			[32]
Lagos				5	2	7	0.181				[5]
Lagos				2	2	4	0.573				[35]
Enugu State		5	5			10	0.16				[36]
Ibadan			-			52			0.15		[34]
Ibadan				6		6			0.01		[33]
Umua-hia						10				31.53–59.81	[23]
Ile-Ife			2	4	4	10	1.49				[37]
Yenagoa			-			-	2.78				[12]
Abuja				1	4	5	2.78				[26]

### 5.2. Waste Segregation

Segregation or sorting is a very essential practice in the management of healthcare waste since about 75% to 90% of the generated waste is often not hazardous, and can easily be handled as general solid waste. The remaining 10% to 25% that are hazardous require specialized handling techniques that are often not cost-effective [28]. Poor segregation of the waste leads to an increased quantity of infectious components since all waste that has come in contact with infectious components is classified as infectious [16]. Waste segregation is therefore a critical determinant of effective healthcare waste management [38]. Hence diligent segregation of waste will yield more quantities of clean stream that would be easier, safer, and cost-effective to manage through recycling, land-filling, and composting [39].

The standard practice is to use a color-coded bag for segregation [6]. This is often the case in developed countries [40]. The simplest and safest waste segregation method is the use of the “three-bin system” where the collected waste is first separated into hazardous and nonhazardous general (which is usually larger in quantity) waste at the point of generation [2]. The separated hazardous component is further sorted into (i) used sharps and (ii) potentially infectious materials. However, the common challenges associated with healthcare waste segregation in developing countries include the absence of waste segregation from source, absence of color coding, non-documentation of data, and poor attitude of the staff [6,41,42]. Although earlier studies on healthcare management in Nigeria reported an absence of sorting/segregation in the healthcare waste management [12,21,43], the later studies show evidence that waste is segregated at the facilities in Nigeria but with inconsistencies in the segregation methods [24,36,44–47]. Afolabi et al. (2017) reported that in tertiary health institutions solid waste from wards was sorted into two types—general and sharps—while waste from the virology department was segre-

gated into four types, which are highly infectious, infectious, general, and sharps. This is not in conformity with WHO's guideline, which states that healthcare waste should be segregated into general waste, pathological waste, infectious waste, sharps, pharmaceutical waste, and radioactive waste [1]. Waste segregation is more commonly practiced in Lagos than in any other state in the country [48]. This is because of the existence of effective government health monitoring units and regulations in the state [45]. The absence and/or improper segregation of healthcare waste has also been reported in other developing locations such as Iran [49], Pakistan [27], and Yemen [50].

### *5.3. Training and Awareness*

Adequate education and proper training of health workers and other stakeholders are essential in ensuring optimal outcomes in healthcare waste management [41]. There is no available data that documented the level of training and awareness of healthcare workers and facility waste handlers on healthcare waste management at the national level in Nigeria. However, there is a significant number of case studies on the level of training and awareness in hospitals (tertiary, secondary, and primary) at different city locations across the country [39,45–48,51–54]. More studies have been done on government-owned hospitals than on private hospitals [38,44]. In the majority of the studies, training of healthcare workers occurs only once after employment and there is little or no subsequent training to update the knowledge of the workers [24,55]. The essential training on occupational health and safety is also lacking [43,55]. There is limited training on healthcare waste segregation among healthcare workers, and facilities often do not have medical waste manuals/instructive posters on waste segregation displayed anywhere on sites [28]. Workers in government hospitals are better trained and equipped with knowledge on effective handling of healthcare waste than those at the private hospital [39]. This might be probably a result of more available resources and a quest for more knowledge. In places across the country, studies have shown that healthcare workers such as doctors, nurses, and midwives have insufficient knowledge of healthcare waste management [55]. This is simply an indication that the quality of training given to the healthcare workers in the facilities may not be adequate and/or standardized in tune with the WHO's guidelines, which may have been responsible for poor knowledge and practice of healthcare waste management in Nigeria [45].

### *5.4. Collection and Storage*

In healthcare facilities, the standard practice is that waste must be regularly collected (at least once a day) to avoid the accumulation of waste at the point of generation [42,56]. To optimize resources in waste management, collected solid waste is usually stored in a designated place before onward transportation to treatment or recycling sites [10]. For healthcare waste, there are specified rules that must be observed in its storage [57]. Some of these include healthcare waste must be stored in a designated area. This area must be closed or secluded with restricted access; protected from rodents, birds, and animals, must be separate from food stores, must be well-ventilated and with adequate illumination [42]. It must also have water and sewerage access [6]. The reviewed studies show that few healthcare facilities in Nigeria maintain storage facilities for healthcare waste. Aside from Lagos state, most storage facilities in Nigeria do not follow stipulated guidelines [36]. The waste containers do not have a lid, are often overfilled, and are not leak-proof/puncture-resistance [46]. The general practice is to have an area in the hospital premise designated for the dumping of waste that is irregularly burnt without due diligence. Most hospitals in Lagos have internal storage facilities for streams of waste collected and stored according to general waste, sharps waste, and infectious waste [35]. This is cogently explained by the strict government regulation and enforcement.

### *5.5. Waste Transportation*

The movement of the collected healthcare waste involves two modes that include on-site transportation and off-site transportation [42,58]. On-site transportation means the movement of healthcare waste within the facility using wheelbarrows, trolleys, containers on a wheel, and/or carts, etc. Off-site transportation of healthcare waste entails its movement outside the facility for onward treatment and disposal. Waste workers handling the transportation must be well equipped with personal protective equipment (PPE) such as masks, gloves, water-proof boots, etc. Wheelbarrows and trolleys were reported as major means of on-site transportation of healthcare waste in Nigeria [5,21]. In some instances, the on-site transportation is done manually by cleaners that carry the waste with their hands/heads without personal protective equipment [36,37,59]. WHO recommends that separate trolleys should be used for different categories of waste but this guideline is not often adopted in Nigeria where one trolley is often used for the movement of all classes of waste. Collection of wastes from the wards to the central storage facilities is carried out daily after cleaning the wards while the frequency of collection from storage facilities to the disposal centers is often reported to be irregular [35,37].

#### *5.6. Disposal and Treatment*

In developing countries, several methods are adopted for healthcare waste treatment and disposal, but incineration seems to be the most favored method because of the quick diminishment of about 90% of the waste and the use of its heat for boiler and energy production [3,60]. Selection of a method for healthcare waste treatment and disposal must be done with the primary aim of ensuring minimum adverse impact on the health and environment [42].

In general, the final disposal of municipal solid waste in Nigeria is the sole responsibility of the government through municipal councils [10]. In Lagos state, for instance, the Lagos State Waste Management Agency (LAWMA) medical unit is responsible for the provision of waste-color-coded bags and sharps boxes as well as the central collection, transportation, and disposal of all medical waste from all healthcare facilities [61]. LAWMA uses “hydroclave” technology for the final treatment of medical waste before landfilling to prevent environmental health pollution [5].

At the national level, there is an existing arrangement where the National Agency for Food and Drug Administration and Control (NAFDAC) participates in the collection and disposal of expired drugs [62]. Nonetheless, these services seem not to be effective with a call for the establishment of disposal centers by state governments.

Analysis of the review shows that in places across the country hospitals often handle the disposal and treatment of their waste by themselves through indiscriminate practices. These hospitals, for instance, maintain open dumpsites where medical waste are openly dumped, burnt, and/or buried without due consideration to the environmental and public health implication [21,24,35,37,43]. Chemical analysis conducted on soil and water samples collected from such open dump sites of healthcare waste shows a high content of lead, cadmium, chromium, mercury, and manganese [43]. This is detrimental to the surrounding community and farms. It could also lead to the pollution of underground water sources.

A study conducted in 2017 to ascertain the healthcare management practices and safety indicators in Nigeria shows that sharp and non-sharp components of healthcare waste were burnt in protected pits in 45.40% and 45.36% of all the sampled healthcare facilities respectively [9]. Only 2.06% of the total sampled healthcare facilities have functional incinerators. Burning of sharp waste without any form of caution is rampant in the northern part of the country and poses tremendous health and environmental risk to the public. For instance, during an opening burning of healthcare waste, a major component of dental waste known as amalgam can discharge mercury vapor, while rubber dams and gloves can liberate dioxins into the atmospheric environment [43]. Mercury vapor and dioxins are dangerous air pollutants.



Another method adopted for medical waste disposal in Nigeria is by dumping the waste along with municipal solid waste at the designated collection centers within urban centers. This waste is not treated before landfilling by the waste management authorities. Healthcare institutions in Abuja, Nigeria's capital city, dispose of all kinds of waste generated in municipal solid waste dumpsites without segregation or any form of pretreatment [26]. Because of the perceived high susceptibility of healthcare waste to contamination, little or no attention is usually paid to its recycling potential in Nigeria [58]. Other methods of healthcare waste treatment and disposal such as microwave irradiation, autoclaving, bioconversion, electron-beam technology, etc. are not practiced in Nigeria. Methods of disposal and treatment of healthcare waste are summarized in Table 2.

**Table 2.** Methods of Disposal and Treatment of Healthcare Waste in Nigeria.

Disposal Method	Locations of Practice	Description	References
Incineration	Across the country	Few (About 2.06%) hospitals have incinerators	[9]
Open Dumping/Burning and Burying	Across the country/Rampant in the northern part of the country	Hospitals maintain open dumpsites where medical wastes are dumped, burnt, and/or buried	[21,24,35,37,43]
Hydroclave	Lagos State	LAWMA adopts hydroclave for treatment of medical waste before landfilling	[5]
Landfill	Lagos State	The medical waste is land-filled after treatment with the hydroclave technology	[5]
Dumping with Municipal Solid Waste (MSW)	Abuja	Medical waste is disposed of at the municipal solid waste dumpsites without segregation or pre-treatment	[26]
NAFDAC	Across the country	NAFDAC participates in the collection and disposal of expired drug	[62]

## 6. Policy Landscapes, Financing Mechanisms, and Institutional Arrangement

The development and implementation of national policy is the first step toward the effective management of healthcare waste by national governments. At the international level, Nigeria has ratified key international conventions related to healthcare waste management, such as (i) the 1992 Basel Convention on the control of trans-boundary movements of hazardous waste and their disposal (ii) the 2002 Stockholm Convention on Persistent Organic Pollutants (POP). Historically, several laws and policies have been made in Nigeria for the protection of the environment and public health (Table 3).

**Table 3.** Some Environmental Health Laws and Regulations in Nigeria.

Scheme.	Law/Decree/Act/Regulation	Year	Area Covered
1	Public Health Act/Ordinance	1917	Food administration, hygiene in public places, urban sanitation, noise and odor control, waste management, etc
2	Public health Service Act	1958 (Amendment of 1917)	Food administration, hygiene in public places, urban sanitation, noise and odor control, waste management, etc
3	Decree No 58	1988	Established FEPA, with the mandate to (i) monitor and enforce environmental protection measures (ii) liaise with other government agencies on environmental protection (iii) establish standards and prosecute offenders
4	Decree No 42	1988	Harmful Waste Special Criminal provision. It prohibits carrying, depositing, and dumping harmful waste and injurious, poisonous, toxic, and noxious substances. It also prescribes penalties for offenders
5	Decree No 86	1992	It sets out a procedure and methods for environmental impact assessment (EIA) on both public and private projects. It also stipulates that the construction of incinerators requires EIA
6	National Effluent Limitation (S.I.8)	1991	It establishes effluent discharge limits and makes it mandatory for firms to install anti-pollution infrastructures for the treatment of their effluents
7	National Pollution Abatement in Industries and facilities generating wastes	1991	Established permissible limit for industrial pollution and puts restrictions on the release of pollution to the environment
8	Management of Solid and Hazardous Waste Regulation	1991	Tracking of waste from the point of generation to the point of disposal with specific details (ii) Hazardous waste treatment, disposal, and the required facilities
9.	NESREA ACT	2007	Establishes NESREA to implement and enforce environmental quality standards and enforce compliance
10	National Environmental (Sanitation and Waste Control) Regulation (S.I.28)	2009	Environmental waste and sanitation, Control of medical and healthcare waste
11	National Environmental Health Practice Regulation	2016	Prevention and control of incidence of contagious diseases through environmental health interventions. Provides for the creation of a waste management advisory committee
12	National Radioactive Waste Management Regulations	2006	Nuclear safety and radiological protection regulation
13	National Environmental (Healthcare Waste Control) Regulations	2021	Regulation of Healthcare waste management

The foremost policy on waste and environmental health management in Nigeria is the Public Health Act of 1917, which was later amended as the Public Health Act of 1958

[63]. The law was made up of regulations on health and environmental issues, such as hygiene at public places like an abattoir, slaughtering of animals, night soil handling, noise and odor control, and other general waste management [64].

However, the creation of the Federal Environmental Protection Agency (FEPA) in 1988 by Nigeria's then-military government has been seen as a major institutional milestone in environmental health management in Nigeria [10]. According to the national environmental health guideline on solid and hazardous waste management issued by FEPA, items categorized as infectious medical waste include culture medium, pathological waste, human blood waste, sharp instruments, animal carcasses, body parts, surgery/autopsy waste, and medical laboratory waste [65]. This guideline further stipulated that the handling of healthcare waste through the stages of storage, transportation, and disposal must be monitored by the appropriate regulatory bodies. FEPA, which was later renamed the National Environmental Standards and Regulations Enforcement Agency (NESREA) in 2009 re-classified healthcare waste into 10 categories that include general solid waste, infectious waste, heavy metal waste, genotoxic waste, microorganisms, pathological waste, pressurized containers, sharps, chemical waste and pharmaceutical waste [66]. The latest regulation, which was specifically issued on healthcare waste management, was released in 2021 [67].

Identifying a need to have a national guideline on healthcare waste management, the Federal Ministry of Environment and the Federal Ministry of Health through the support of various international aid agencies, such as UNICEF, WHO, and World Bank, etc instituted a committee to develop the National Healthcare Waste Management Plan in 2006 [68]. In 2013, the national healthcare waste management policy was collaboratively prepared by the Federal Ministry of Environment and the Federal Ministry of Health [69]. However, no law has been made by the national assembly on healthcare waste management to back up this policy [38]. As of 2016, there were no modalities for the enforcement of healthcare waste management policy and plan in Nigeria at the either national, state, or local government level [5]. In a survey of 1921 healthcare facilities across the country, only 44.8% had their healthcare waste management plan adapted from the 2013 national healthcare waste management policy and only 41.4% of the surveyed hospitals had designated staff or units for healthcare waste management [44], although this was reported as an improvement against the zero status that was reported in the previous literature [32].

Nonadherence to the environmental and health guidelines in handling healthcare waste was reported in studies conducted in Nigerian locations, such as Umuahia [23] and Yenogoa [12]. This is a result of the absence of specific budgets and financial allocations to cater to waste management within healthcare facilities [58]. The aftermath is poor staff welfare and lack of job satisfaction, which are partly responsible for poor healthcare waste handling among hospital cleaners [43]. Poor or no training of healthcare workers on the management of healthcare waste reported widely in the literature is also a pointer to the poor funding available to the health sector in the country [70]. In most healthcare facilities in Nigeria (both government and privately owned), there were no specific budgets or financial allocations for healthcare waste management [36,58].

Few healthcare facilities in Nigeria have a written policy or code of conduct to protect healthcare waste workers against occupational hazards, and no insurance coverage or compensation packages for the workers in cases of exposure [55]. The majority of workers handling the waste lack working tools and infection control materials, which makes them unsatisfied [43].

Considerable evidence from the review has also shown that the activities of waste managers in healthcare facilities are rarely subjected to administrative scrutiny or supervision [55]. The only exception is Lagos state where compliance with the healthcare waste management guideline issued by Lagos state is enforced by the Health Facilities Monitoring and Accreditation Agency (HEFAMAA). Their job function includes ensuring compliance by issuing healthcare waste certification to facilities that subscribed to the

LAWMA services. This certification is a prerequisite for the annual renewal of operating licenses [45].

## 7. Prospects and Challenges for Healthcare Waste Management in Nigeria

The healthcare waste management in Nigeria as reviewed in the foregoing sector is in a deplorable state with the prospect of further deterioration because of factors such as an unmitigated upsurge in the general and urban populations and the country's dwindling economic fortune and abysmal institutional governance that has affected the general waste management administration in the country. It is based on these facts that we discuss the challenges and prospects for healthcare waste management in Nigeria in what follows:

- a. **Inadequate financing:** Managing solid waste in cities across the world is a great challenge because of the economic resources required for both capital and recurrent expenditure [10]. Capital expenditures are incurred when procuring waste management facilities such as incinerators, waste vehicles, autoclaves, construction of landfills, etc. Recurrent expenditures are in the form of the cost of maintaining equipment, the cost of energy for powering the equipment, the cost of training, wages, and working tools for waste workers, etc. The ability of a nation to tackle its waste management issues is, therefore largely dependent on the availability of economic funds. Adequate provision of materials and resources for healthcare waste management will ensure proper collection, segregation, treatment, and disposal and will also minimize the incidence of nosocomial infection [46]. There is no budget allocation by hospitals and the government specifically devoted to healthcare waste management in Nigeria. Rather, budgets are allocated for general municipal solid waste management that involves only solid waste collection and disposal without consideration for other components of waste management such as training, segregation, waste characterization, etc. Hospitals across the country usually pay only monthly fees to the waste management authorities/agencies for the collection of the municipal solid waste component of their waste. The hazardous component of healthcare waste is not the responsibility of the agency to handle (except for Lagos state). This is because they are not properly equipped to handle hazardous waste. Because of this, healthcare facilities handle this waste by either burning or burying it. Only a few hospitals have incinerators. Incineration is the most widely used technology for hospital waste disposal in developing countries [60]. Disposal of hospital waste through incineration has its advantages such as occupying limited land space, over 90% of the waste can be diminished, and generated heat can be channeled to useful purposes such as burning of boilers and energy generation [71]. However, when not properly operated, waste incinerators can be a major source of air pollution [71]. The harmful emissions from incineration, which include dioxins and heavy metals, can remain in the air for a long time constituting environmental and public health risks [60].
- b. **Training, sensitization, and awareness:** Implementation of proper training and awareness has several positive impacts on the optimal management outcome of healthcare waste [5]. The foregoing review indicated that the level of training and awareness on healthcare waste management in the country is still poor. Partly affecting this poor training outcome is the absence and/or poor availability of funds. In many healthcare facilities where training and awareness programs exist, it happens once without a subsequent program for continuous retraining of the staff. There is also an indication that the quality of the training in some instances is below standard. Another area where training is effective is in healthcare waste minimization. It means adopting processes and practices that will prevent waste before it is generated. It will help in increasing the amount of clean waste stream, which will eventually reduce the cost of disposal and the adverse impact on the environment. One

way to achieve waste minimization in healthcare facilities is by training the hospital management on the source reduction measures such as the adoption of a supply method that is less wasteful and prone to produce less hazardous material [72].

- c. **Effective Legislature:** There is an inadequate legislative framework for healthcare waste management in Nigeria. Apart, from Lagos state, which issues and enforces guidelines on the proper management of healthcare waste. No other state in Nigeria has implemented a law on healthcare waste management. Even with the recent guideline on healthcare waste delivery issued by NESREA, there is a need for appropriate laws to be made for effective implementation and enforcement. The absence of this law has led to indiscriminate disposal of medical waste by healthcare facilities across the country since there are no attached sanctions for noncompliance. Healthcare legislature should also enforce the provisioning of adequate working tools and an enabling work environment for the waste workers. It was reported in Malaysia that even after the provision of a healthcare waste management policy and training to the staff, poor waste segregation continued in the healthcare facilities because of the absence of tools required for the segregation [73]. Effective healthcare waste management law should also enforce the creation of waste management teams/committees within healthcare facilities. This will ensure that healthcare waste-related issues receive quick and adequate attention. The absence of policy and poor policy regimes contributes to the fact that there is no waste management committee available in health facilities in the country [44].
- d. **Data Collection:** Accurate mining of data is essential in waste management planning and execution. Data on waste management in Africa, such as collection and generation, are relatively scant [74,75]. There is no documented data on healthcare waste management in Nigeria at the national, state, and local government levels. The non-documentation of healthcare waste management data is because of the absence of effective and operational guidelines. Effective healthcare waste management data collection will include quantitative and qualitative information on waste management, such as waste collection rate, waste generation rate, waste composition, waste characterization, level of training and awareness, waste management staff strength, quantities of healthcare waste incinerated, quantity landfilled, the quantity of recyclables collected, etc. Proper training on healthcare waste workers, adequate funding, and the creation of waste management committees within health facilities are factors that could promote adequate and prompt waste data collection and documentation across the country.
- e. **Efficient waste treatment techniques:** High capital, maintenance, and operational costs are one of the major factors that impede the acquisition and use of novel waste treatment technologies in developing countries such as incinerators, and biochemical waste conversion equipment [76]. However, there are reasonable ranges of technologies for the treatment of medical waste that may be appropriate for use in low and middle-income countries. A typical example is a cost-effective mechanical-biological treatment technology suggested by [77] for the pre-treatment of waste before disposal or landfilling. This technology was specifically designed for low-and middle-income countries. It stabilizes organic waste and ensures the production of waste-derived fuels as it converts waste to energy in the form of fuel [10]. It promotes the concept of circular economy, by simultaneously ensuring energy production, solid waste management, as well as other socioeconomic and environmental health advantages, such as reduction of landfill gas emission, leachates pollution, and unpleasant odor. With the appropriate collaboration between hospitals and indigenous research institutes in Nigeria, these technologies can be locally produced to make them cost-effective. To achieve this, there should be a collaborative assessment of the contextual problems and the devising of a management strategy that would be suitable to their economic circumstance and also sustainable for use based on local contextual conditions.

## 8. Recommendations and Conclusions

Healthcare waste management is a challenge to most developing countries and it poses a risk to the environment and public health when not properly managed [27]. The current review on the status of healthcare waste management in Nigeria has revealed many challenges and also shows areas for improvement. Relying on this, we make further recommendations for this work. First, financing healthcare programs should also consider funding for the management of the generated waste. To achieve this, there is a need for a waste management committee to be formed wherever medical waste is generated to facilitate the proper use of these funds for oversight of infectious waste disposal.

Second, legislation that will guide healthcare waste management in Nigeria needs to adopt a multidisciplinary approach. We hold this opinion because healthcare waste management is interdisciplinary in scope and therefore would need the involvement of several stakeholders such as public health engineers, the private sector, nongovernmental organizations, and even informal sectors. This can be achieved by organizing conferences, seminars, and public hearings to capture variants of ideas and opinions for effective legislation. Experience has shown that engaging policymakers through advocacy during the planning period to strengthen immunization and waste management committees for immunization programs helped in the quick and safe disposal of immunization waste while building the capacity of the key actors [78]. We also believe that this method of engaging policymakers should also be adopted by healthcare facilities managers, municipalities, and at the state government level.

The Nigerian Population Commission (NPC), in collaboration with international aid agencies, has collected data on health indicators through the Demographic and Health Survey (DHS) program. This data has been collected every five years since 1990. It is our opinion that the DHS program should be reorganized to also collect data on healthcare waste management in Nigeria.

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