Scientific Research Publishing

Open Journal of Applied Sciences, 2024, 14, 1080-1120
https://www.scirp.org/journal/ojapps
ISSN Online: 2165-3925
ISSN Print: 2165-3917

Development and Application of Integrated Indicators for Assessing Healthcare Waste Management Systems in Kenyan Hospitals

Muriithi Jackson Githinji[1], Paul Mwangi Njogu[2], Zipporah Nganga[3], Mohamed Karama[4]

[1]Institute of Tropical Medicine and Infectious Diseases (ITROMID), Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[2]Institute of Energy and Environmental Technology, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya
[3]Academic, Research and Student Affairs, South Eastern Kenya University, Kitui, Kenya
[4]School of Public Health, Amref International University, Nairobi, Kenya
Email: jacksonmuriithigm2020@gmail.com

How to cite this paper: Githinji, M.J., Njogu, P.M., Nganga, Z. and Karama, M. (2024) Development and Application of Integrated Indicators for Assessing Healthcare Waste Management Systems in Kenyan Hospitals. *Open Journal of Applied Sciences*, **14**, 1080-1120.
https://doi.org/10.4236/ojapps.2024.144072

Received: January 30, 2024
Accepted: April 23, 2024
Published: April 26, 2024

Abstract

Healthcare waste management (HCWM) is an important aspect of healthcare delivery globally because of its hazardous and infectious components that have potential for adverse health and environmental impacts. The paper introduces a set of indicators for assessing HCWM systems in hospitals. These indicators are: HCWM policies and standard operating procedures, management and oversight, logistics and budget support, training and occupational health and safety, and treatment, disposal and waste treatment equipment housing. By plotting a mark on a continuum which is defined as good and poor on the extremes and is connected with all other marks in a spoke arrangement, it's possible to describe a baseline for HCWM in any specific hospital. This baseline can be used to improve awareness of the actors and policy-makers, compare the same hospital at a different point in time, to compare observations by different evaluators and to track improvements. Results suggest that in Kenya, the application of such indicators is useful for evaluating which priorities should be addressed to improve outcomes in HCWM systems. Systematic sampling technique was used to identify and collect data by use of observational checklist, interviews, visual verification and review of documents and a HCWM assessment tool. The objective is to suggest an integrated management tool as a method to identify prevailing problems with a HCWM system. The method can be replicated in other contexts worldwide, with a focus on the developing world. The integrated indicators focus on management of HCW and not its potential impact on human health and environment, an area recognized to be critical for future research.

Keywords

Developing Countries, HCW Management Indicators, Management Tools

1. Introduction

The management of HCW in developing countries poses public health and environmental concern due to poor handling processes [1] and inadequate treatment [2]. The absence of effective activities for healthcare waste (HCW) minimization, segregation, and recycling [3], and the low levels of training of healthcare workers, waste handlers and consciousness of waste legislation, policies and standard operating procedures [4], increase the spread of diseases [5], decreasing the quality of the service provided and the security of the operators [6]. The growth of the world population and the introduction of use of disposable medical products has led to increase of HCW generation [7]. This has enhanced difficulties in HCW management, particularly in low- and low-middle income countries [8] [9]. The factors that have been used in earlier studies to estimate the generation rates of HCW in hospitals include the income of the country [10], are number of beds [11] and the number of occupied beds [12]. Generation rates vary in low-middle income countries and range from 0.02 to 3.2 $kg \cdot bed^{-1} \cdot day^{-1}$, since the healthcare facilities in rural areas, towns and cities differ [13]. Therefore, in low-income countries, inadequate data on HCW generation, the absence of programs for waste minimization, appropriate treatment and trained personnel affect HCWM planning [14] [15].

The application of management tools for planning HCWM solutions is of great importance. A HCW management tool was developed and applied in a real case study at municipal level and in three public hospitals of La Paz-Bolivia where the following five management indicators were applied to assess infectious waste management, 1) collection and selective collection (SC); 2) storage; 3) local treatment; 4) maintenance and monitoring; and 5) awareness, security and prevention [16]. A set of indicators was introduced in a Brazilian public institution for assessing the quality of the HCWM system in order to quantify the HCW produced [17]. Another set of five indicators for assessment of HCWM, budget support, developing policies and legislation, technology and knowledge administration, treatment and final disposal issues, and quality of the collection and transportation system were later introduced [18]. A prediction model for measuring the HCW generation rate for proper handling of infectious waste also exists [19]; while a form-based checklist, in parallel with quantitative analysis of the HCW had been used to assess the quality of the HCWM system in a healthcare facility in Brazil [20]; and a set of parameters for reviewing the scientific literature about HCWM systems was later introduced [21]. These integrated indicators were introduced in order to assess the HCWM systems using quantita-

tive and qualitative data. However, the indicators reviewed are limited to approaches suited specifically for the study areas investigated or related to quantitative assessments, providing restricted analysis. Other authors suggested that there is a need for holistic approaches and information platforms for the decision-making process in HCWM [22] for improving scaled capacity building and public awareness [23] and that the indicators used as management tools for HCW should continually be improved in other future studies [16]. Therefore, the present study contributes to the implementation of a holistic approach for HCWM generated in hospitals, based on quantitative and qualitative assessments, a topic investigated in many contexts worldwide [24].

The objective is to propose an integrated tool suited for developing areas and replicable in other hospitals, in order to develop a novel and common method for comparing and commenting on the pros and cons of the HCWM systems of low-middle income countries. For evaluating the state of a HCWM systems in an integrated way, an indicator set was developed and applied according to the management directives presented by the World Health Organization (WHO) in 2014 [25]. The five integrated indicators developed and applied in this study to assess HCWM systems included: HCWM policies and standard operating procedures, management and oversight, logistics and budget support, training and occupational health and safety of healthcare workers and waste handlers including incinerator operators, and treatment, disposal and incinerator housing. For assessing the potentiality of its application, the indicators were implemented in Kenya, a low-middle income country where HCWM systems are still under development. The tool is applied in five county hospitals in Kenya focusing on minimization, storage, collection, transportation, treatment, disposal, monitoring and staff awareness [26] [27]. The aim of the research is to introduce the management tool developed to provide the results of a real case study.

2. Literature Review

Healthcare facilities (HCFs) are the main HCW producers. The most common term used to describe waste generated by HCFs is healthcare waste (HCW). There are several other terms such as medical waste, biomedical waste, clinical waste or health facility waste [28]. HCW is defined as all types of waste generated from HCFs, whether it is a hazardous or harmless material, and whether it is infectious or non-infectious in nature or a chemical [29]. It is estimated that HCWs constitute approximately 1% - 2% of total produced urban waste [30]. A total of 85% of the total amount of waste generated as a result of healthcare activities is non-hazardous while 15% are hazardous materials, which are infectious, radioactive or toxic. The majority of HCW generators are hospitals, medical centers, laboratories, veterinary clinics, research centers, mortuaries, blood banks and nursing homes. In low-income countries, HCW is often not segregated into hazardous and non-hazardous waste, making the actual amount of produced hazardous waste much higher [31] [32]. HCW amounts have continued to in-

crease, and health facilities around the world are producing more waste than ever before. The amount of HCW generation continue to rise with the increase in the world's population, medical facilities' multitude and with the widespread inclination to use disposable medical equipment. Due to the use of advanced technological practices and safety considerations, single-use equipment causes more waste generation [33].

Problems in HCW management are more prevalent in developing countries that produce several hundred tons of waste daily. Studies performed in Ethiopia revealed that 35% of healthcare institutes collect and dispose of needles, syringes and other sharp objects in a way that that healthcare personnel and the general public constantly exposed to increasing risk and injury [34]. These countries typically use HCW management methods such as landfilling, recycling, incineration or storage. Although HCW landfilling without pre-treatment is prohibited, it is the most common method of HCW disposal as it is a cheap and easy method. In practice, HCW is stored in open dumps in pits mixed with municipal waste and is then incinerated [35] [36]. Further problems include a lack of health risk awareness associated with HCW, insufficient training in proper waste management, inadequate human resources and the low priority given to this matter [35]. HCW can have a long-lasting effect on human health, both for the people handling, collecting and recycling the waste, and for the general public. The environment is also suffering from fresh water and soil contamination resulting from untreated HCW pollution or by the process of surface waste burning [37] [38].

HCW and by-products are generated as a result of diagnosis, treatment, medical intervention or the immunization of human or animals [39]. They cover a wide range of materials and different categories that include sharps waste, infectious waste, pathological waste, pharmaceutical waste, cytotoxic waste, chemical waste, radioactive waste and general waste [32] [35] [40]. The purpose of healthcare systems is to provide medical solutions to patients and save their lives, but sometimes serve as disease reservoirs where healthcare personnel and communities are exposed due to unsanitary methods of disposing of HCW [41]. Poorly managed HCW can cause long-term and undesirable risks to human health and is a potential source of re-infection, posing a significant threat to the environment. Therefore, the management of HCW which forms an integral part of any national healthcare system should be given top priority [42]. Safe HCW management practices reflect on HCF service quality and cover all activities related to the minimization, generation, segregation, transportation, storage, treatment and disposal [43]. Further, a good outcome in this process in hospitals depends on adherence to HCW management legal frameworks, policies, plans and standard operating procedures [44]. Healthcare facilities' managers are responsible for introducing and ensuring an appropriate waste management system, as well as supervising the compliance with appropriate procedures of all medical staff. Therefore, appropriate education and training systems must be available to all

personnel responsible and engaged in both segregation and waste collection processes [45]. In line with WHO guidelines, waste segregation practices should be standardized across the country and included in national regulations for HCW management [32]. The key to the effective management of HCW is the segregation process at the point of waste generation. Segregation means the separation of various types of waste into different color-coded containers with corresponding color coded liners at places where they are generated as a first step in HCW management [46].

The main objective that should be achieved by low-income countries is the proper segregation of infectious and non-infectious wastes at generation points, which is an essential step towards mitigating environmental and health risks [47]. However, the HCW segregation rate suffers from the insufficient application of operating procedures, which should be introduced to reduce costs [48]. In Cameroon, HCW is disposed of in open dumps mixed with MSW or disposed of in incinerators that are often poorly designed, due to the lack of an integrated approach to policy making [49]. In Iran, the lack of separation of HCW, specific regulations, proper waste treatment and disposal along with MSW, were the main problems detected in introducing a sustainable HCW management system [50]. In Ghana, many hospitals do not have any segregation or disposal programs for pharmaceutical waste and more than half of the population disposed of pharmaceutical waste through the MSW that ends up in the landfills or dump sites [51]. However, it has been proved that the segregation of HCW decreases the costs of its management in hospitals [52], so it should be considered in order to improve environmental, social and economic sustainability.

According to WHO recommendations concerning segregation and collection, a general waste container should be black. Sharp, infectious and pathological waste containers should be marked yellow. Chemical and pharmaceutical waste container should have a brown colour. It is also recommended that almost all waste categories should be collected at least once per day, or when three-quarters of the container is filled. The exceptions to this are pharmaceutical, chemical and radioactive waste, which can be collected on demand [53]. After segregation, waste is collected and transported outside the hospital or healthcare facility. The transportation of HCW is usually performed using dedicated trolleys and containers. The trolleys have to be cleaned and disinfected daily. Hazardous and non-hazardous waste has to always be transported separately [54]. HCW should be stored in designated rooms and appropriate safety and security measures should be taken. In general, non-hazardous, infectious and sharp, pathological, pharmaceutical, chemical and radiological waste should be stored separately in different places with different characteristics depending on the waste stored [25].

The most common types of HCW treatments are steam-based treatments (autoclaving, microwave and frictional heat treatments), which are used to disinfect/sterilize highly infectious and sharp waste by subjecting them to moist

heat and steam. Steam sterilization is used for sterilization instruments and for sharp and hazardous HCW treatments. To reduce the volume of HCW, steam sterilization can be combined with mechanical processes, such as mixing, grinding and shredding [53]. Incineration, the process of HCW destruction by burning, removes hazardous materials, reduces their mass and volume and converts them into ashes. An incinerator that is not properly designed or operated, or is poorly maintained, emits toxic substances into the environment. If incinerators operate at low temperatures, they generate emissions containing dioxins and furans, which may cause health problems as they are carcinogenic [55]. Incinerators operating at 850˚C - 1100˚C and containing special gas-cleaning equipment can comply with international emission of dioxin and furan standards. Dioxin-control technologies use activated carbon (AC) adsorption. Before flue gas flows into the dust-collection equipment, AC is injected to adsorb the dioxin and then is blocked by a bag filter [56]. The next method used is a chemical treatment process. It mostly relies on using disinfectants, ozone treatment and alkaline hydrolysis. Composting and vermicomposting (which uses earthworms to consume and recycle the organic waste) are successfully used to break down hospital kitchen waste, as well as other digestible organic and placental waste. Another example of a biological process is the natural decomposition of pathological waste through its burial. Non-hazardous waste should be recycled and regularly collected by the municipalities or transported by the facility to public landfills [53]. Inadequate HCW treatment can be dangerous for health. Incinerator control results in the release of small particulates that affect the functioning of the respiratory and cardiovascular systems. Volatile metals, such as mercury, lead, arsenic and cadmium, will damage the immune and neurological systems, as well as the kidneys, brain and lungs. The incineration of high-metal-content materials leads to the spread of toxic metals in the environment [57]. Various studies have shown adverse health effects in populations in the vicinity of incinerators, including cancer and reproductive dysfunction [58] [59].

Results of incineration of HCW is gaseous emissions and bottom ash which are also hazardous. Incinerator bottom ash analyses carried out in Tanzania revealed presence of heavy metals (iron, cadmium, lead, copper and manganese) [60]. HCW is almost always contaminated with pathogens, and leaching toxic heavy metals and chemicals from solid HCW into the soil occurs in poorly designed dump sites and landfills. The leachate can penetrate into the soil and contaminate crops, surface and groundwater resources, posing a risk to human health through water consumption. To control the safety of these methods, hydro-geological conditions must be considered. Landfills should have restricted access, control scavenging, use a soil cover regularly, manage waste discharge, and control surface water and drainage [61].

One study showed a possibility of thermal energy, fuel, and electric-power production from HCW through waste-disposable syringes treated with pyrolysis at 400˚C - 550˚C were used to produce liquid fuel. The produced pyrolysis oil

had physical properties similar to that of a diesel or petrol mixture [62]. Pyrolysis of mixed medical waste, such as plastic, cotton and glass, at 500˚C have been shown to produce liquid fuel (pyrolysis oil) [63]. These studies bring hope that in the future it will be possible to use HCW to produce energy or fuel on a large scale. The application of recycling of sterilized plastic and metal parts, mechanical needle removers, safe transport and storage, appropriate treatment, documentation, training and equipment maintenance can improve the quality of HCW management systems, reducing environmental and health risks [13]. The steam autoclave is most commonly used to sterilize HCW as an alternative to incineration technologies [64]. However, other appropriate technologies can be considered [25]. Studies in developing countries have shown evidence that HCW is mixed and collectively combined with municipal waste or burned in the open air [65]. Such activities pose risks to public health and the environment. HCW can contain potentially harmful microorganisms that can infect healthcare professionals, patients and the general public. Potential risks include the release of toxic compounds into the environment, such as heavy metals, polycyclic aromatic hydrocarbons (PAH), dioxins and furans and drug-resistant microorganisms that spread from HCFs into the environment [32] [66].

In order to reduce the risk associated with HCW, it is necessary to develop and implement policies and procedures for the proper use of single-use or reusable items and the identification of recycling options. There is need to engage manufacturers and suppliers to avail biodegradable materials, or that can be reused for secondary purposes. Another option is to minimize the impact by adjusting purchasing strategy and inventory control. This solution can also be implemented through the use of physical (steam treatment) instead of chemical disinfection, waste minimization by using less materials and finally by checking the expiry date of the products upon delivery and refuse to accept items with short ones [32] [67]. Major challenges related to the risk of HCW are misconceptions and a lack of education and awareness regarding which type of waste is hazardous and which is not. In particular, educating healthcare professionals on the proper segregation and disposal of different waste types would be very beneficial to waste reduction and proper infection control [68]. In summary, the risks of HCW can be significantly reduced by implementing appropriate measures. This would result in fewer illnesses and accidental sharps injuries, but also less environmental pollution [69].

3. Materials and Methods

3.1. Study Area

The study was conducted in five county hospitals in Kenya numbered from 1 - 5. These hospitals were selected purposively and were distributed across the regions from Coast, Eastern and Rift Valley.

3.2. Study Locations

This included Hospital 1 (3.3833˚S, 38.5667˚E), Hospital 2 (2˚16'30.00"S,

37˚49'12.00"E), Hospital 3 (1.0833˚S, 35.8667˚E), Hospital 4 (0.3500˚N, 37.5833˚E), and Hospital 5 (1.0167˚N, 35.0000˚E).

3.3. Study Design

A cross sectional study design was adopted and qualitative and quantitative data was collected.

3.4. Data Collection Tools

The integrated HCW management tool was used together with observational checklist, interviews, visual verification and review of documents.

3.5. Developing the HCW Assessment Indicators

The study introduces an integrated indicator set that was developed to facilitate assessment of HCW management systems in the hospitals sampled. The HCW management indicators and criteria used in this study are in agreement with the guidelines provided by [25]. The starting point for the application of the indicators is to obtain local and current reliable data from the hospitals which should be collected by an impartial expert in the field of HCWM. Therefore, fieldwork and cooperation with local hospital administration are important for administering questions in the indicator set contained in the assessment tool. The experts working in the areas being appraised should be targeted to answer questions on each criterion under each of the indicators contained in the assessment tool. Four methodologies should be adopted for completing the indicators:

- assessment of hospital policies, plans and standard operating procedures of HCWM;
- interviews with hospital directors, nurses, local medical engineers, and waste operators;
- Observation and visual verification during field inspection of HCWM generation, storage and collection, transportation, treatment and disposal areas;
- review of local documentation of HCWM (policies, standard operating procedures, minutes, audit protocols, commodities stock records in stores, IPC training records).

The assessment tool is structured as a function of the five indicators developed and applied to assess knowledge and practice of hospital technical managers (Infection, prevention and control coordinators, medical superintendents, hospital administrators and public health officers in charge of HCW management) and administrators. Other data collection methods that included observation, interviews, visual verification and review of documents (policies, standard operating procedures, minutes of meetings, service provision audit protocols, commodities stock records in stores, IPC training records) were used. Conducting interviews to health workers is a method used in other case studies [70]; in this study, the indicators would provide an integrated approach for its

appraisal, which can be replicable in other contexts. The structure of the indicators introduced by [71] for the assessment of municipal solid waste (MSW) management systems in developing countries was used and adapted for the specific analysis of HCW. Such an approach is similar to what others have introduced before, [21], although it was implemented for a literature review, whereas in this research it is implemented for a real study. Other indicators that focus on five key areas of analysis which included: budget support, developing policies and legislation, technology and knowledge administration, treatment and final disposal issues, and quality of the collection and transportation system exists [18]. In this type of study aiming to calculate the level of performance of the selected county hospitals in HCW management, a methodology where several indicators are used for scoring and ranking outcomes was modified and adopted [71] [72] [73] [74]. In this study, the indicators used for scoring and ranking hospitals HCWM systems included; policies and procedures, management and oversight of HCW management systems, logistics and budget support, training of healthcare workers, waste handlers, incinerator operators, and occupational safety and health, and treatment, disposal and infrastructure.

Each indicator set is divided into seventeen to thirty-two criteria. The assessment tool containing the five indicators was used to rank the hospitals overall performance in HCW management. Each correct answer in the appraisal tool earned a score of one and the total per performance indicators calculated as a percentage which was interpreted as per the predetermined ranking scale and scoring criteria. An aggregate score in each of the five appraisal indicators between 0% - 49% had a ranking score of one (1) and was interpreted as poor, scores between 50% - 74% had a ranking score of two (2) and interpreted as fair while those assessment indicators that had scores of 75% and above had a ranking score of three (3) and were interpreted as good (**Table 1**). The indicators used in this study to assess the county hospitals' HCW management systems can be applied in baseline data collection, monitoring progress, and evaluation of HCW management interventions, and for comparing different same level hospitals within countries and in particular those in low and middle income countries. The indicators are presented as percentages, from 0% to 100%, by a radar scheme. The rank scores were then used for presentation in a radar where the further a score was from the centre of the radar, the better the performance level [71] [72] [73].

Table 1. Ranking scale and Scoring Criteria.

Performance Score Range (%)	Rank	Interpretation
0 - 49	1	Poor
50 - 74	2	Fair
75 - 100	3	Good

3.6. Implementation of the HCWM Indicators in Hospitals

The criteria considered for assessing the HCWM system in hospitals were divided into five indicators:

A) HCWM policies and standard operating procedures,

B) Management and oversight,

C) Logistics and budget support,

D) Training and occupational health and safety

E) Treatment, disposal and incinerator housing.

Each indicator provides information regarding the topic considered, using qualitative and quantitative data about the management activities applied in the hospitals.

For each hospital, the information about its size should be presented, in order to compare the data with other hospitals: number of beds; percentage of beds occupied per year; number of patients per year; number of workers; and HCW produced per year. The indicators were chosen in order to provide a complete view of the HCWM system of the hospitals. The first step towards appraising health waste management system is the assessment of availability and utilization of HCWM policies and standard operating procedures by hospital management and HCWM actors. Second, existence and functionality of management and oversight structures is assessed. Effective functionality of this indicator is critical to ensure coordination of availability of HCW storage commodities at generation points, protection of waste handlers during collection and transportation and safety of the incinerator operators at the treatment and disposal sites. Third, provision of adequate and appropriate logistics for efficient and effective HCW management is critical. This is made possible through prioritizing financing of HCWM through the hospital budgets. Such dedicated budgets voted to support HCWM should be used to procure commodities (bins and bin liners, trolleys, PPEs etc.) to enhance segregation of HCW, development of information. Education and communication (IEC) materials and commodity procurement plans, commodity quantification tool, and a waste collection schedule. Fourth, the prevention system and the awareness of local operators is assessed in order to quantify the capacity of the operators in reducing the risk of cuts and contamination. Lastly, the fifth indicator is to assess treatment, treatment equipment disposal options offered at the facility to reduce pollution of the environment that consequently affects human health. The housing of the equipment is also assessed in order to quantify the capacity of the operators in reducing the risk of contamination. This indicator assesses operation and maintenance of the equipment through functionality of the equipment, whether the equipment has a temperature regulation device, waste treatment SOPs, availability and use of equipment operator's manual and a maintenance schedule. A waste treatment equipment that is effectively operated and maintained will reduce emissions that pollute the air and consequently affect human health. The detailed assessment tool used is provided in **Tables 2-6**.

Table 2. Criteria used to assess indicator A. HCWM policies and standard operating procedures.

Indicator code	Number	Criterion	Description
A. HCWM policies and standard operating procedures	A1	Availability of National plan and guidelines for HCWM	This criterion used to assess availability and use of National HCW Management plan and National guidelines for safe management of HCW at the hospitals
	A2	Access to the National HCWM plan	This criterion used to assess if interviewees could access the National HCWM plan
	A3	Understanding of the national plan	This criterion used to assess interviewees ability to discuss the contents of National HCWM plan
	A4	Availability of HCWM guidelines	This criterion used to assess availability of the Kenya National Guideline for safe management of HCWM at the hospital
	A5	Access to the National HCWM guideline	This criterion used to assess if interviewees had access to the National guideline for safe management of HCWM
	A6	Understanding of the national HCWM guidelines	This criterion used to assess interviewees ability to discuss the contents and if knowledgeable on the National HCWM Guideline
	A7	Domestication of the national HCWM plan	Hospital had its own HCWM plan signed by facility In-Charge
	A8	Availability of domesticated plan to staff	The hospital plan was available to all hospital staff
	A9	Training requirement and safety procedures	The hospital plan outlined occupational safety and hospital staff training requirements
	A10	HCWM system Audit procedures	The hospital plan outlined HCWM audit procedures
	A11	Understanding of the domesticated plan	Interviewees had access and were knowledgeable of the contents of hospital plan
	A12	Handling, treatment and disposal SOPs	SOPs for handling, treating and disposal of infectious waste were available
	A13	Handling and transportation SOPs	SOPs for in house handling and transportation of infectious waste were available
	A14	Liquid waste disposal SOPs	SOPs for disposal of liquid waste were available
	A15	laboratory chemical decontamination SOPs	SOPs for chemical decontamination of laboratory waste were available
	A16	Blood and blood products SOPs	SOPS for disposal of blood and blood products were available
	A17	Laboratory Vacutainers SOPs	SOPs for laboratory vacutainers were available
	A18	Placenta handling and disposal SOPs	SOPS for handling and disposal of Placenta were available
	A19	Incineration SOPs	SOP for Incineration operation and record keeping were available
	A20	Maintenance and repair SOPs	SOPs for Incinerator maintenance and Repair

Table 3. Criteria used to assess indicator B. Management and Oversight.

Indicator code	Number	Criterion	Description
B. Management and Oversight	B1	IPC committee	Presence of an active IPC committee
	B2	IPC meeting	Whether committee had met in the last 3 months
	B3	HCWM in minutes	Whether HCWM appeared in IPC committee minutes
	B4	Audit checklist	Whether IPC committee had an audit checklist
	B5	Inclusion of HCWM	Whether checklist included HCWM issues
	B6	HCWM audit	Whether IPC committee had conducted HCWM audit in the last 6 months
	B7	Addressing gaps after audit	Whether IPC committee had addressed gaps identified in HCWM audit

Continued

	B8	Giving feedback	Whether IPC committee had given feedback to hospital management after audit
	B9	IPC committee composition	Whether the IPC committee was multi-disciplinary in its composition
	B10	Appointment of HCWM in charge	Whether there was an officer appointed as in-charge of HCWM in the hospital
	B11	HCWM in charge and hospital policy	Whether HCWM in-charge had been identified in the hospital policy
	B12	Job description	Whether the hospital policy contained job description for the HCWM in-charge
	B13	Facility audit	Whether there was evidence that HCWM in-charge had carried out facility audit within 3 months
	B14	Supervisors inspections	Whether supervisors of the various sections had conducted any inspections for HCWM within the past 2 months?
	B15	Evidence of inspections	Whether there was evidence of such inspections
	B16	Evidence of inspection checklist	Whether section supervisors had IPC inspection checklists
	B17	Training and OSH requirements	Whether the supervisors checked their employees HCWM training or Occupational Health requirements?

Table 4. Criteria used to assess indicator C. Logistics and budget support.

Indicator code	Number	Criterion	Description
C. Logistics and budget support	C 1	Segregation	Waste segregation was being practiced
	C 2	Color coding	Recommended colour coding and labelling was in use
	C 3	Bins and Bin liners	Coded bins and bin liners were available
	C 4	Segregation guidelines	Waste segregation was done according to guidelines
	C 5	Sharp containers	Sharp containers were available in sharp generation areas
	C 6	Sharp containers positioning	Sharp containers were positioned within arm's length
	C 7	Matching of bins and liners	Whether coded bins were matched with bin liners
	C 8	Segregation posters	IEC materials of signage were placed near bins
	C 9	Posters in wards	HCWM/BCC posters were placed at departmental wards
	C 10	Availability of collection schedule	Schedule for waste collection was available at collection point
	C 11	Use of waste collection schedule	Availability and use of a waste collection schedule from waste generation points
	C 12	Trolleys	Availability and use of trolleys
	C 13	Functionality of trolleys	Were the trolleys availed functional?
	C 14	General waste dedicated trolley	Was there a dedicated trolley for general waste?
	C 15	Infectious waste dedicated trolley	Was there a dedicated trolley for infectious waste?
	C 16	Commodity procurement plans	Presence of hospital commodity procurement plans
	C 17	Updated plans	The procurement plans were up to date
	C 18	Inclusion of commodities in plans	Procurement plan addressed all HCWM commodities
	C 19	Commodity stock outs	Hospital experienced stock out of HCWM commodities within the previous 6 months
	C 20	Dedicated budget	There was a dedicated budget for HCWM
	C21	Quantification tool	Hospital had a HCWM quantification tool

Table 5. Criteria used to assess indicator D. Training and occupational health and safety.

Indicator code	Number	Criterion	Description
D. Training and occupational health and safety	D1	Appropriate PPEs for IO	Incinerator Operators (IO) use appropriate PPEs
	D2	Condition of PPEs	PPEs worn by IO are in good condition
	D3	appropriate PPEs for WH	Waste handlers (WH) use appropriate PPEs
	D4	Condition of WH PPEs	PPEs worn by WH are in good condition
	D5	IPC training	HCW trained on IPC
	D6	Documentation of training	IPC training documented
	D7	Training on HCWM	HCW trained on HCWM
	D8	Training new employees	Induction training on HCWM to new employees
	D9	Documentation of HCWM training	HCWM training documented
	D10	% health workers trained	More than 60% HCW trained
	D11	Documentation of WH training	WH trained and training documented
	D12	Training of Incinerator operators (IO)	IO trained on safe management and final disposal of HCW
	D13	Basic Incinerator maintenance	IO trained on basic maintenance
	D14	Incinerator operations	IO trained on incinerator operations
	D15	Sharps injury surveillance register	Availability of sharps injury surveillance register
	D16	SOP on injury	Availability of documented procedures in case of injury
	D17	Log book register	Needle stick injuries and other incidents documented in a log book register
	D18	SOP on Post Exposure Prophylaxis (PEP)	Availability of documented post exposure prophylaxis (PEP) protocols
	D19	Employee SOP PEP Knowledge	Employees are knowledgeable of PEP procedures
	D20	PEP availability	Availability of PEP to staff for 24 hours per day
	D21	Use of Personal Protective Equipment (PPEs)	Availability and use of heavy duty gloves
	D22	Use of PPEs	Availability and use of boots covering feet
	D23	Use of PPEs	Availability and use of overalls/aprons
	D24	Use of PPEs	Availability and use of face masks
	D25	Use of PPEs	Availability and use of Goggles
	D26	Use of PPEs	Availability and use of respirators
	D27	Use of PPEs	Availability and use of heavy duty gloves
	D28	Use of PPEs	Availability and use of boots covering feet
	D29	Use of PPEs	Availability and use of overalls/aprons
	D30	Use of PPEs	Availability and use of face masks
	D31	Use of PPEs	Availability and use of goggles
	D32	Use of PPEs	Availability and use of Respirators

Table 6. Criteria used to assess indicator E. Treatment, Disposal and Incinerator Housing.

Indicator code	Number	Criterion	Description
E. Treatment, disposal and incinerator housing.	E1	Recording of waste generated	Evidence of recording of waste generated from various departments
	E2	Incinerator mechanical status (IMS)	Functionality of the Incinerator
	E3	IMS	Provision of temperature regulation device
	E4	IMS	Functionality of the calibrated temperature device
	E5	IMS	Provision of Preventive maintenance log book for the incinerator
	E6	Waste treatment plant guidelines	Operation of waste treatment plant as per guidelines
	E7	waste treatment plant SOP	Operators have SOPs for waste treatment plant
	E8	Equipment operation SOP	SOPs followed in the equipment operation
	E9	Use of Manufacturers operator manual	Equipment manufacturer's operator manuals readily available to the operator
	E10	Monitoring of equipment usage	Operation logs used to monitor equipment usage
	E11	Use of data collected	Data collected from the logs used to improve service
	E12	Incinerator maintenance schedule	Waste treatment equipment maintained in a proactive manner to minimize downtime and optimize performance
	E13	Spare parts	Equipment spare parts locally available
	E14	Maintenance contract	Presence of service maintenance contract for the equipment
	E15	Equipment backup procedures	Presence of backup procedures for equipment failure
	E16	Environmental safeguards	Waste treatment equipment in use pose harm to local community/environment
	E17	Housing	Provision of wash room at the incinerator site
	E18	Housing	Provision of running water at incinerator site
	E19	Housing	Provision of concrete floor at incinerator-built site

Indicator A: HCWM policies and standard operating procedures

This indicator provides criteria for assessing availability and utilization of policies and standard operating procedures. Table 2 reports the description of the twenty criteria used. The first (A1, A4, A8) criteria is to assess availability of policies, national guidelines and domesticated hospital HCWM plan, while criteria A2 and A5 are to assess access of the policies and national guidelines of HCWM by the healthcare workers at the hospital. Criteria A3 and A6 assesses level of understanding of the policies and the national guidelines of HCWM by the HCW. Criteria A7 assesses whether the hospital has a HCWM plan in line with the national one while A11 assesses HCWs access to the plan and knowledge of its contents. Criteria A9 assesses whether the hospital has set out training requirements and safety procedures that protect healthcare workers, waste handlers, incinerator operators, patients and the community from injury and contamination that emanates from the process of HCWM. Criterion A10 assesses whether the hospital plan contains a self-auditing procedure. Criterion A12 to A20 assesses availability of standard operating procedures (SOPs) for

handling, treating and disposal of infectious waste, handling and transportation, liquid waste disposal, laboratory chemical decontamination, disposal of blood and blood products, disposal of laboratory vacutainers, placenta handling and disposal, incinerator operation and record keeping, and incinerator maintenance and repair respectively.

Indicator B: Management and Oversight

This indicator provides criteria for assessing management and oversight structures put in place within the hospitals to facilitate HCWM. Table 3 reports the description of the seventeen criteria used. Criteria B1 and B2 assesses presence of an Infection Prevention and Control (IPC) committee, and whether this committee had held a meeting within the last three months respectively. Criterion B3 establishes whether HCWM issues were discussed and appeared in the IPC committee minutes while B4 assesses whether the IPC committee had an audit checklist and B5 assesses HCWM inclusion into the audit checklist. Criteria B6, B7 and B8 assesses whether IPC committee had conducted HCWM audit in the last 6 months, had addressed gaps identified in HCWM audit, and whether audit feedback was given to the hospital management respectively. Criterion B9 assesses whether the IPC committee was multi-disciplinary in its composition while B10 assesses whether an officer had been appointed as in-charge of HCWM in the hospital. Criterion B11 assesses whether the position of a HCWM in-charge had been identified in the hospital policy and B12 assesses whether a job description for this officer appeared in the hospital HCWM policy. Criterion B13 assesses the functionality of HCWM officer through establishing existence of a report of hospital audit carried out in the last three months as evidence. Criterion B14 assesses whether departmental supervisors had HCWM conducted inspections while B15 looked for an inspection reports conducted in the last two months as evidence. Criterion B16 assessed whether section supervisors had IPC inspection checklists while B17 assessed whether the supervisors checked their employees HCWM training or Occupational Health requirements.

Indicator C: Logistics and budget support

This indicator provides criteria for logistics and budget support structures put in place within the hospitals to facilitate HCWM. Table 4 reports the description of the twenty-one criteria used. Criteria C1 to C9 assesses issues pertaining to waste segregation, color coding and labelling, availability and use of color coded bins and bin liners, whether waste segregation was done according to guidelines, sharps containers were available in waste generation areas, sharps containers were positioned within arm's length, whether coded bins were matched with bin liners, segregation posters appropriately placed and waste segregation posters appropriately placed at departmental wards respectively. Criteria C10 to C15 assesses HCWM collection, availability of a waste collection schedule at collection points, use of a waste collection schedule from waste generation points, availability and use of trolleys, functionality of waste collection trolleys, provision of a dedicated trolley for general waste and for infectious waste. Criteria C16 to C21

assessed presence of hospital commodity procurement plans, whether the procurement plans were up to date, whether procurement plan addressed all HCWM commodities, whether hospital experienced stock out of HCWM commodities within the previous 6 months, whether there was a dedicated budget and that the hospital had a HCWM quantification tool respectively.

Indicator D: Training and occupational health and safety

This indicator provides criteria for assessing training and occupational health and safety procedures put in place within the hospitals to facilitate HCWM. Table 5 reports the description of the thirty-two criteria used. The indicator is appraised to ensure that healthcare workers, waste handlers and incinerator operators are provided with and wear personal protective equipment when at work. The expert appraising should also check on whether training has been conducted to new hires and practicing healthcare workers and those involved in storage, collection, transportation, treatment and disposal of HCW. Knowledge of existence and use of a twenty-four-hour post-exposure prophylaxis (PPE) protocols should be established. Vaccination of healthcare workers, waste handlers and incinerator operators against hepatitis B virus that can be transmitted through needle stick injuries should be assessed. Criteria D1 to D4 deals with assessment of provision and use of appropriate personal protective equipment to waste handlers and incinerator operators. Criteria D5 to D12 assesses training of waste handlers, incinerator operators, and HCW. They also assess induction training of new employees and documentation of training. D13, D14 and D15 assess training of incinerator operators on basic maintenance, incinerator operation and need to maintain a sharps injury surveillance register. Criterion D16 assesses availability of documented procedures in case of injury and D17 assesses availability and use of a needle stick injuries and other incidents documented in a log book register. Criterion D18 assesses whether documented post exposure prophylaxis (PEP) protocols are available while D19 assesses whether employees are knowledgeable of PEP procedures. Criterion D20 assesses availability of PEP to staff for 24 hours per day while D21 to D32 assess availability and use of different types of PPEs.

Indicator E. Treatment, Disposal and Incinerator Housing

This indicator provides criteria for assessing HCWM treatment, disposal and incinerator housing put in place within the hospitals. Table 6 reports the description of the nineteen criteria used. Criterion E1 looks for evidence of recording of waste generated from various departments within the hospital and E2 assesses the mechanical status of the incinerator. Criteria E3 to E5 establishes provision of temperature regulation device, functionality of calibrated temperature device and incinerator preventive maintenance log book respectively. Criteria E6 to E16 assesses use of guidelines during incinerator operation, SOPs, availability of operator's manual, monitoring of incinerator usage, use of data collected to improve service, availability of a maintenance schedule, availability of incinerator spare parts locally, availability of a service maintenance contract,

availability of a backup option for waste treatment in case of equipment failure and the status of environmental safeguards respectively. Criteria E17 to E19 assesses provision of water and sanitation facilities within the waste treatment plant.

4. Results and Discussion

4.1. Application of the Indicators in Five Hospitals in Kenya

The indicators were applied in five hospitals in Kenya as an example for presenting the potentiality of the methodology in a low-middle income country. A study that included five hospitals was carried out in five hospitals in Kenya, in order to assess qualitatively the generation, storage, collection, transportation, treatment and disposal of HCW. The five hospitals studied were considered the most representative of the HCWM system in rural Kenya, due to their size, extent of clinical area and waste generation. Information gathered through filling of the appraisal/indicator tool about the HCWM in these hospitals is provided in the results section. Data about the HCW yearly generation was not available. This represents a limitation of the study and of the HCWM system, underlined within the Results and Discussion sections.

The quantities of waste and the features of the hospitals chosen for implementing the indicators are reported in Table 7. Hospital 1 generates about 23.38 - 39.48, hospital 2, 21.37 - 36.09, Hospital 3, 36.30 - 61.28, Hospital 4, 38.74 - 65.415 and hospital 5, 48.54 - 81.96 tonnes of HCW per year. The significant variation in HCW generation can be a function of various factors: period of the year, day of the week, number of in and out patients, seasons in a year, units in healthcare, MCH/FP, surgery, emergency unit, obs/gyn ward, maternity ward, paediatrics ward, pharmacy, laboratory, VCT unit, TB follow up unit, dental unit, mortuary among others. It underlines the difficulty of HCWM and planning in this structure, a hidden issue if only average data is provided.

Hospital 2, with about 21.37 - 36.09 tonnes of HCW generated per year and 97 beds available, and 15 other departments can be considered smaller and generated the least amounts per year than all the other hospitals. Hospital 5 with an annual generation rate of 48.54 - 81.96 tonnes had 250 beds and cots, and 26 other departments. The HCW generation rates were not reported by all the hospitals and therefore adopted from the results published from a study done in Kenyan hospitals that documented HCW generation rates of between 0.61 kg/bed/day to 1.03 kg/bed/day [75]. There was no data on total number of healthcare workers, waste handlers and incinerator operators from the five hospitals and therefore not reported in either Table 7 or Table 8.

A brief description of the five hospitals, according to the site visits and interviews, is provided below, following the structure of the indicator set.

Hospital 1

1) HCW management policies and standard operating procedures (SOPs)

Table 7. Qualitative data on the five hospitals in Kenya.

Hospital No.	No. of wards	No. of other depts.	Total No. of beds and cots	Average bed occupancy rate (%)·day^{-1}	NO. of beds and cots occupied·day^{-1}	HCW generated per bed·day^{-1} (kg)	Total HCW generated·day^{-1} (kg)	Total HCW generated·year^{-1} (Tons)
1	4	17	112	93	105	0.61 - 1.03	64.05 - 108.15	23.38 - 39.48
2	4	15	97	98	96	0.61 - 1.03	58.56 - 98.88	21.37 - 36.09
3	5	15	170	95.6	163	0.61 - 1.03	99.43 - 167.89	36.30 - 61.28
4	7	21	248	70	174	0.61 - 1.03	106.14 - 179.22	38.74 - 65.415
5	8	26	250	87	218	0.61 - 1.03	132.98 - 224.54	48.54 - 81.96

The HCW generation rates of between 0.61 kg/bed/day to 1.03 kg/bed/day as documented in a study done in Kenyan hospitals were used to calculate the total HCW generated·day^{-1} (kg) [75].

Table 8. Qualitative data on Post Exposure Prophylaxis for the five hospitals in Kenya.

Hospital No.	Annual OPD attendance	Annual out-patient Injections	No. of clients with occupational exposures	Number receiving PEP
1	26,419	1260	5	4
2	69,990	8217	67	39
3	0	1	6	5
4	34,744	1859	84	47
5	96,671	6317	138	121

HCW policies and SOPs were qualitatively evaluated using the criteria set (Table 2) and scored 33.3% which had a ranking score of 1 which was interpreted as poor (Table 1). This was due to the hospital not having the national HCWM plan and therefore healthcare workers not being knowledgeable on the national aspirations of HCWM. Although the hospital had the national guidelines for safe handling of HCW, the guidelines had not been disseminated to the healthcare workers and were therefore not aware of their role in ensuring safety in the process of HCWM. The national HCWM plan and the guidelines had not been domesticated leaving healthcare workers without guidelines on occupational safety, training requirements and audit procedures. Hospital 1 had not developed SOPs on safe handling, treatment and disposal of infectious waste, disposal of liquid waste, chemical decontamination of laboratory waste, disposal of blood and blood products, laboratory vacutainers, placenta handling and disposal, incineration operation and maintenance, record keeping and repair which are critical in reducing health risks from HCW.

2) Management and oversight structures for HCWM

HCW management and oversight structures were evaluated using the criteria set (Table 3) and scored 41.2% which had a ranking score of 1 and was interpreted as poor (Table 1). Hospital 1 had put an infection prevention and control (IPC) committee in place and had met and discussed HCWM in the past three months. This hospital had developed an IPC audit checklist which also included HCWM. It was noted that the IPC committee had informed the hospital man-

agement and addressed gaps identified during the audits. However, the IPC committee had serious gaps in that it had not addressed gaps identified within the last six months, IPC committee was not multidisciplinary, HCWM in charge had not been identified in the hospital policy and therefore not appointed. There was no job description for that position and therefore no evidence of that the in charge had carried out any inspections in the last three months. The supervisors of various departments and sections had not developed an IPC inspection checklist and there was no evidence of inspections within the past two months. The supervisors had not checked whether employees had been trained and met the occupational health and safety requirements.

3) Logistics and budget support

Hospital 1 scored 77.8% on making of provision for HCWM logistics and budget support when evaluated using the criteria set (**Table 4**), a ranking of 3 and was interpreted as good (**Table 1**) and was second to hospital 4 on this indicator. Although there were no segregation posters placed near the color coded bins, this hospital scored 80% which was good (score of 3) when the criterion for assessing healthcare workers waste segregation and color coding practices were assessed. Hospital 1 did poorly with 0%, a ranking score of 1 (**Table 1**) when availability, functionality and use of HCW transportation equipment from storage to treatment sites was evaluated. There was no HCW collection schedule and dedicated trolleys for transporting infectious waste to treatment sites. Hospital 1 score 87.7% when the criteria set was assessed. The hospital had a dedicated budget, an up to date procurement plan which addressed HCWM commodities and had not experienced HCWM commodities stock outs for the last 6 months

4) Training and occupational health and safety

Hospital 1 scored 46.7% when evaluated on criteria set (**Table 5**) for this indicator, ranking score of 1 and was interpreted as poor (**Table 1**). Incinerator operators used appropriate PPE, there was evidence of IPC and HCWM training to healthcare workers and waste handlers. Incinerator operators had not been trained on safe management and final disposal of HCW. An assessment on sharps surveillance and availability of post exposure prophylaxis to ensure occupational safety and health showed that there was a sharps injury surveillance register with a lack of a document procedure to be followed in case of an injury. All the needle stick injuries and other accidents were documented in a logbook register, there lacked a post exposure prophylaxis protocols. PEP to all members of staff was availed for 24 hours and employees were aware of PEP procedures to be followed. None of the PPEs for waste handlers was provided leaving them exposed to all the health risks associated with handling of HCW. Use of PPEs by the incinerator operators was assessed and it was found heavy duty gloves, boots, overalls and face masks were provided and being used leaving out googles and respirators which are important in ensuring occupational safety and health. Only one out of five enlisted for PEP did not receive.

5) Treatment, disposal and infrastructure

Hospital 1 scored 20% which was a ranking of 1 and interpreted as poor when evaluated qualitatively using the criteria set (Table 6) for assessing treatment, disposal and availability of sanitation facilities in the infrastructure provided for the incinerator (Table 1). The incinerator was in use, the incinerator infrastructure had a concreate floor which was easily cleansable, the operator had SOPs for waste treatment plant and equipment had a maintenance contract. There was lack of evidence of recording of waste generated from various departments, calibrated temperature regulation device, running water at the site, preventive maintenance logbook for the incinerator, available SOPs not used, operators' manual, operation logs, equipment spare parts, maintenance schedule and the waste treatment equipment posed harm to human health and the environment since it lacked air pollution control devises.

Hospital 2

1) HCW management policies and standard operating procedures

The HCWM policies and standard operating procedures can be qualitatively evaluated at 33.3% which has a ranking score of 1 using the criteria set (Table 2), and which was interpreted as poor (Table 1). This was due to the hospital not having the national HCWM plan and therefore healthcare workers not being knowledgeable on the national aspirations of HCWM. The hospital did not have the national guidelines for safe handling of HCW, the guidelines had not been disseminated to the healthcare workers and were therefore not aware of their role in ensuring safety in the process of handling HCW. The national HCWM plan and the guidelines had not been domesticated leaving healthcare workers without guidelines on occupational safety, training requirements and audit procedures. Hospital 2 had not developed SOPs on safe handling, treatment and disposal of infectious waste, disposal of liquid waste, chemical decontamination of laboratory waste, disposal of blood and blood products, laboratory vacutainers, placenta handling and disposal, incineration operation and maintenance, record keeping and repair.

2) Management and oversight structures

Although hospital 2 had appointed an in charge of HCWM, all criteria set (Table 3) for effective management of HCW were lacking leaving the hospital with a score of 5.9%, a ranking score of 1 which was interpreted as poor. This hospital lacked IPC committee and therefore no HCW management and oversight structures put in place to forestall the effects of pollution to human health and the environment.

3) Logistics and budget support

Provision of HCWM logistics and budget support is critical. Hospital 2 was evaluated using the criteria set (Table 4) and scored 44.4%, a ranking of 1 which was interpreted as poor (Table 1). There was HCW segregation practiced in hospital 2 together with use of the recommended color codes for the bins and bin liners. Sharp boxes were availed and placed in all sharps generation areas and coded bins were matched with bin liners. However, waste segregation was

not done according to guidelines, no HCW segregation charts displayed and there were no waste collection schedules displayed at the generation areas. There were no dedicated trolleys provided for waste transportation to treatment sites. This hospital didn't have an up to date commodity procurement plan in place and a HCWM qualification tool, and only depended on what was supplied from the national commodity supply agency. This hospital had suffered HCWM commodity stock outs and had no dedicated budget.

4) Training and occupational health and safety

This hospital 2 was evaluated using the criteria set (Table 5) and scored 40%, a ranking score of 1 which was interpreted as poor (Table 1). Although the incinerator operators used PPEs that were in good condition, they were not the recommended ones for them. There was evidence that healthcare workers and waste handlers (WH) were trained on IPC and WH wore recommended PPEs that were in good condition. An assessment on sharps surveillance and availability of post exposure prophylaxis to ensure occupational safety and health showed that there was a sharps injury surveillance register with a lack of a documented procedure to be followed in case of an injury. This could be the reason this hospital recorded a higher number (Table 8) of who had occupational exposures. All the needle stick injuries and other accidents were documented in a logbook register, there lacked a post exposure prophylaxis protocols. PEP to all members of staff was availed for 24 hours and employees were aware of PEP procedures to be followed. PPEs provided to waste handlers included boots and overalls leaving them without heavy duty gloves, face masks and respirators and therefore exposed to all the health risks associated with handling of HCW. Use of PPEs by the incinerator operators was assessed and it was found that heavy duty boots, overalls and face masks were provided and being used leaving out googles and respirators which are important in ensuring occupational safety and health.

5) Treatment, disposal and infrastructure

Hospital 2 scored 5% when the criteria set (Table 6) were assessed qualitatively for treatment, disposal and availability of sanitation facilities in the infrastructure provided for the incinerator operators, a ranking score of 1 which was interpreted as poor (Table 1).

The incinerator was in use without any of the requirement set out in the criteria for assessment and the waste treatment equipment posed harm to human health and the environment since it lacked air pollution control devises.

Hospital 3

1) Policies and standard operating procedures

Hospital 3 was evaluated using the criteria set (Table 2) and scored 55.5% in this indicator, a ranking of 2 and interpreted as fair (Table 1). This hospital had the national HCWM plan and the guidelines which were also accessible to healthcare workers who could discuss their contents. In spite of having these documents, this hospital had not domesticated any of them. SOPs for handling, treating and disposal of infectious waste, disposal of laboratory vacutainers, handling and disposal of placenta, incineration and record keeping, and incine-

rator maintenance and repair had not been developed.

2) Management and oversight structures

In the indicator of development of management and oversight structures, hospital 3 was evaluated using the criteria set (Table 3) and scored 70.6%, a ranking of 2 which was interpreted as fair (Table 1). In all the criteria assessed, the IPC checklist developed was deficient of HCWM issues, HCWM in charge had not been identified and job description not availed, the department in charges did not have inspection checklists and could not produce evidence of any inspections conducted within their areas of work.

3) Logistics and budget support

Hospital 3 was evaluated using the criteria set (Table 4) and scored 66.7%, a ranking of 2 and which was interpreted as fair (Table 1). In the logistics and budget support indicator, healthcare workers waste segregation and color coding practices, trolley availability, functionality and use, and availability of HCWM commodity procurement plans and budget allocation were assessed. This study found that HCW was not segregated according to guidelines, sharps containers were not positioned at the recommended arm's length locations, bins and bin liners were not matched, and there was no segregation chart displayed at waste generation points. The hospital had no dedicated trolleys for general waste and for infectious waste. The hospital had not developed a HCW quantification tool, the procurement plan did not address all HCWM commodities and therefore had experienced stock outs in the last six months.

4) Training and occupational health and safety

Hospital 3 was evaluated using the criteria set (Table 5) and scored 40%, a ranking of 1 which was interpreted as poor (Table 1). In this indicator where training of healthcare workers, waste handlers and incinerator is assessed, hospital 3 had no evidence of having conducted IPC and HCWM training to healthcare workers and waste handlers. Incinerator operators had not been trained on basic incinerator maintenance. To strengthen sharps surveillance and to ensure availability of post exposure prophylaxis and reduce health risks, this hospital had implemented all what was set as criteria. The waste handlers were not provided with heavy duty gloves, overalls, face masks, goggles and respirators. The incinerator operators lacked heavy duty gloves, boots, face masks goggles and respirators. This hospital lacked reliable data on PEP (Table 8).

5) Treatment, disposal and infrastructure

Hospital 3 was evaluated using the criteria set (Table 6) scored 45%, a ranking of 1 which was interpreted as poor (Table 1). The hospital had half of what is set as criteria for good practice. In this indicator where treatment equipment, its use, maintenance and sanitation at the infrastructure are assessed, this hospital was lacking provision of a washroom for the operator, no running water, no preventive maintenance logbook, no operators' manual, spare parts and service contract for the waste treatment equipment were not available.

Hospital 4

1) HCW management policies and standard operating procedures

Hospital 4 was evaluated using the criteria set (Table 2) and scored 44.4%, a ranking of 1 which was interpreted as poor in this particular indicator. Availability and access of HCWM policies at the facility was assessed and national HCWM plan and guidelines were lacking making it not possible for the healthcare workers to understand their contents. This hospital had not developed its own HCWM plan leaving the healthcare workers without occupational safety and hospital staff training requirements, and IPC and HCWM audit procedures. This hospital operated without SOPs for in-house handling and transportation of infectious waste, disposal of liquid waste, incineration operation and record keeping, and incinerator maintenance and repair.

2) Management and oversight structures

Hospital 4 was evaluated using the criteria set (Table 3) and scored 64.7%, a ranking of 2 and interpreted as fair in performance of this indicator (Table 1). The hospital met most of the criteria set for assessing management and oversight structures put in place for HCWM but HCWM in charge and job description had not been identified in the hospital policy, there were no evidence of any inspections conducted in the previous two months, no IPC inspection checklist and the supervisors had not checked their employees training or occupational health requirements.

3) Logistics and budget support

Hospital 4 was evaluated using the criteria set (Table 4) and scored 88.9%, a ranking of 3 and interpreted as good (Table 1). This was the highest in this indicator when compared to other hospitals. This hospital scored well in all the criteria set for the assessment of HCW segregation and color codding practices, but only missed display of segregation charts near points of waste generation. This hospital had developed and used a waste collection schedule, dedicated transportation trolleys for general waste and infectious waste. The HCWM commodity procurement plans were available and requisite budget allocated. However, this hospital lacked a HCWM quantification tool which might have led to stock outs of essential HCWM commodities in the past six months.

4) Training and occupational health and safety

Hospital 4 was evaluated using the criteria set (Table 5) in this indicator together with hospital 5 and had the highest score of 60%, ranking of 2 and interpreted as fair (Table 1). Waste handlers and incinerator operators were provided with appropriate PPEs and healthcare workers had been trained on IPC. Incinerator operators had been trained on safe management of HCW and final disposal of HCW. However, IPC training had not been documented, healthcare workers had not been trained on handling HCW, new hires had not been trained on waste management, and incinerator operators had not been trained on operation and maintenance of the waste treatment equipment. Hospital 4 performed well in the criterion on sharps surveillance and availability of post exposure prophylaxis to ensure occupational safety. They maintained a sharps injury surveillance

register, had a documented procedure in case of injury, the hospital had a log-book register to document needle stick injuries and other incidents, there was evidence of documented PEP protocols, employees were knowledgeable of PEP procedures, and PEP was available to staff for 24 hours per day. Use of PPEs by the waste handlers was assessed and it was found that only heavy duty boots were provided leaving out heavy duty gloves, overalls, facemasks, googles and respirators which are important to ensure occupational safety and health. Use of PPEs by waste handlers was the opposite for incinerator operators who were availed and used all the PPEs.

5) Treatment, disposal and infrastructure

Hospital 4 was evaluated using the criteria set (Table 6) and scored 10%, a ranking score of 1, which was interpreted as poor (Table 1). Out of all the criteria set for this indicator, this hospital missed all of them except having a functional incinerator which was on a concreate floor.

Hospital 5

1) HCW management policies and standard operating procedures

Hospital 5 was evaluated using the criteria set (Table 2) and scored 44.4%, a ranking score of 1, which was interpreted as poor (Table 1). This hospital missed HCWM national plan and guidelines and therefore the interviewees were not aware of the contents of the two policy documents. Hospital 5 had not developed its own HCWM plan leaving the healthcare workers without occupational safety and hospital staff training requirements and HCWM audit procedures. The hospital had developed SOPs for handling, treating and disposal of infectious waste, chemical decontamination of laboratory waste, and one for disposal of blood and blood products leaving out all other set out in the criteria (Table 2).

2) Management and oversight structures

Hospital 5 was evaluated using the criteria set (Table 3) and scored 35.3%, a ranking of 1, which was interpreted as poor (Table 1). This hospital missed most of the set criteria (Table 3). There was an IPC committee in place which had conducted HCWM audit in the past six months and addressed the gaps identified in the audit tool. The hospital had identified a HCWM in charge and departmental in charges had conducted inspections and ensured that employees were trained on HCWM and that they meet occupational health and safety requirement.

3) Logistics and budget support

Hospital 5 was evaluated using the criteria set (Table 4) and scored 55.6%, a ranking of 2 and interpreted as fair (Table 1). In the area of segregation and color coding practices of HCW by the healthcare workers, sharps containers were not place at arm's length and color coded bins were not matched with bin liners. There were no dedicated trolleys for general and infectious waste, HCWM commodity procurement plans and requisite budget allocation.

4) Training and occupational health and safety

Hospital 5 was evaluated using the criteria set (Table 5) and scored 60%, ranking of 2 and interpreted as fair (Table 1). The criteria set to assess healthcare workers, waste handlers and incinerator operators training on occupational health and safety were missed with this hospital only training incinerator operators on safe management and final disposal of HCW together with basic incinerator maintenance. This may explain the high numbers (121) of occupational exposures recorded in hospital 5 (Table 8). The hospital scored all the criteria set for assessment of sharps surveillance and availability of PEP to ensure occupational safety. There was a low uptake of PEP in this hospital with only 47 receiving out 84 whom been exposed (Table 8). Waste handlers were not provided with any of the PPEs except boots. The incinerator operators were provided with all the PPEs assessed except goggles.

5) Treatment, disposal and infrastructure

Hospital 5 was evaluated using the criteria set (Table 6) and scored 10%, a ranking score of 1, which was interpreted as poor (Table 1). Out of all the criteria set for this indicator, this hospital missed all of them except having a functional incinerator and running water at the waste treatment site.

4.2. Use of Indicator Scores to Describe the Baselines for HCWM by Plotting a Mark on a Continuum

The introduction of the indicator set allows the hospitals to be compared in a simple scheme. The results of the scores obtained for the five hospitals in Kenya, are in agreement with the previous section, and are reported in Figure 1 (Hospital 1), Figure 2 (Hospital 2), Figure 3 (Hospital 3), Figure 4 (Hospital 4), Figure 5 (Hospital 5) and Figure 6 that presents average score of the five hospitals when all the indicators are combined. Moreover, in Table 9, the quality of the data collected is reported for each of the indicators and for each of the hospitals.

In hospital 1, the indicator on logistics and budget support scored the highest (77.8%), a rank of 3 which was interpreted as good level of HCWM while the indicator on treatment, disposal and infrastructure scored the least (20%), a rank of 1 which was interpreted as poor level of HCWM. According to the assessment criteria set (Table 1), this hospital scored poorly in the other three indicators with scores ranging from 20% for treatment, disposal and infrastructure to 44.7% for training of healthcare workers, waste handlers and incinerator operators on HCWM handling, health risks and safety requirements. This hospital had an overall score of 43.4%, ranked as 1 and interpreted as poor, when all the indicators were combined to form an integrated criterion of assessing the level of HCWM systems (Table 9). In Hospital 2, all the indicators assessed scored poor with scores ranging from 5% to 44.4%, ranked as 1 and interpreted as poor (Table 1) and scoring 25.72% as overall for HCWM system, ranked as 1 and interpreted as poor (Table 1) when the five indicators were combined to form an integrated criterion of assessing the level of HCWM systems (Table 9).

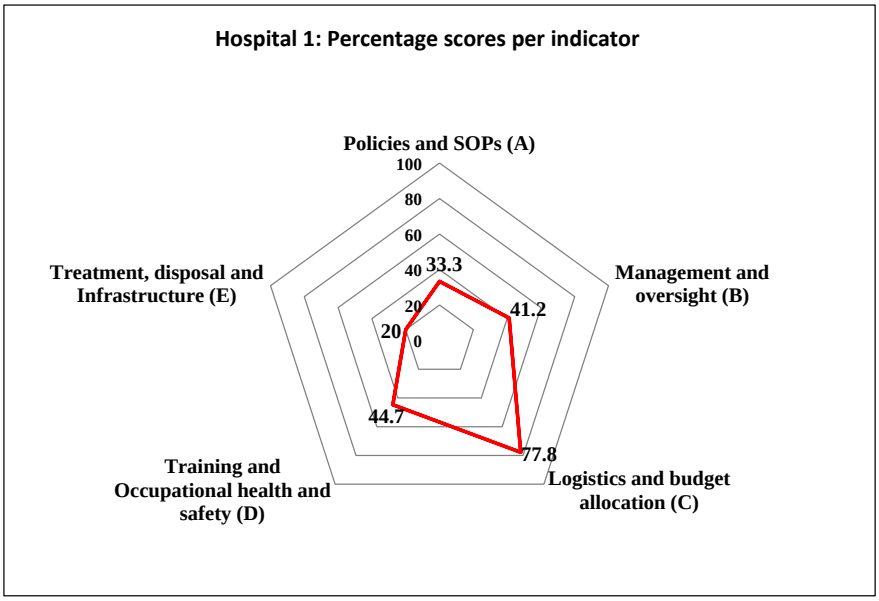

Figure 1. HCWM system assessed in hospital 1.

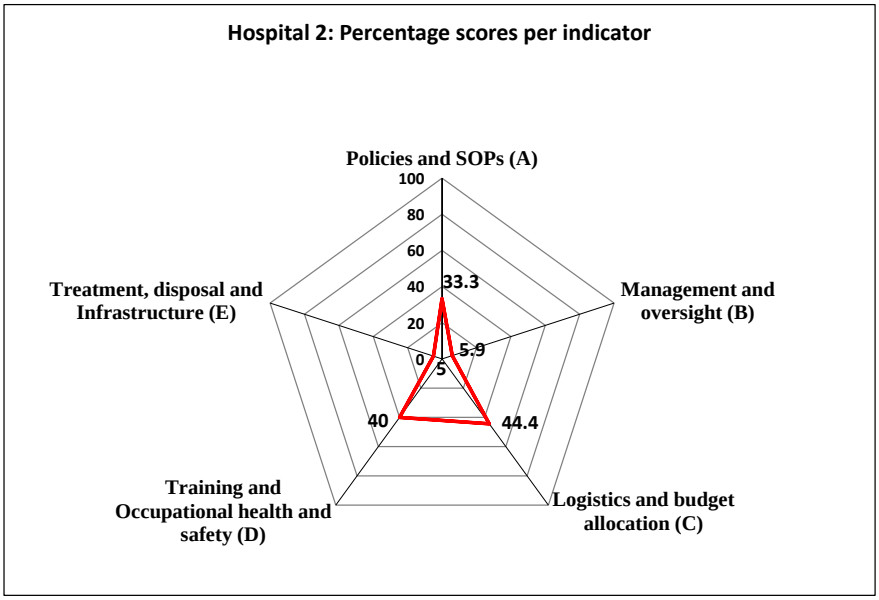

Figure 2. HCWM system assessed in hospital 2.

Table 9. Data quality of the information used to complete the indicators at the hospitals.

Indicators	Hospital 1		Hospital 2		Hospital 3		Hospital 4		Hospital 5	
	% score	Rank	% score	Rank	% score	Rank	% score	Rank	% score	Rank
A	33.3	1	33.3	1	55.5	2	44.4	1	44.4	1
B	41.2	1	5.9	1	70.6	2	64.7	2	35.3	1
C	77.8	3	44.4	1	66.7	2	88.9	3	55.6	2
D	44.7	1	40	1	40	1	60	2	60	2
E	20	1	5	1	45	1	10	1	10	1
Average	43.4	1.4	25.72	1	53.56	1.6	53.6	1.8	41.06	1.4

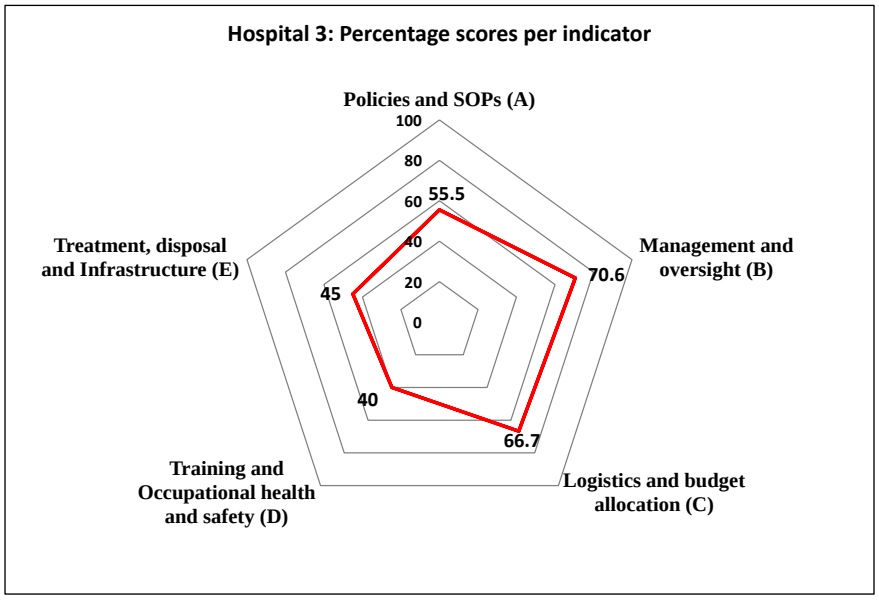

Figure 3. HCWM system assessed in hospital 3.

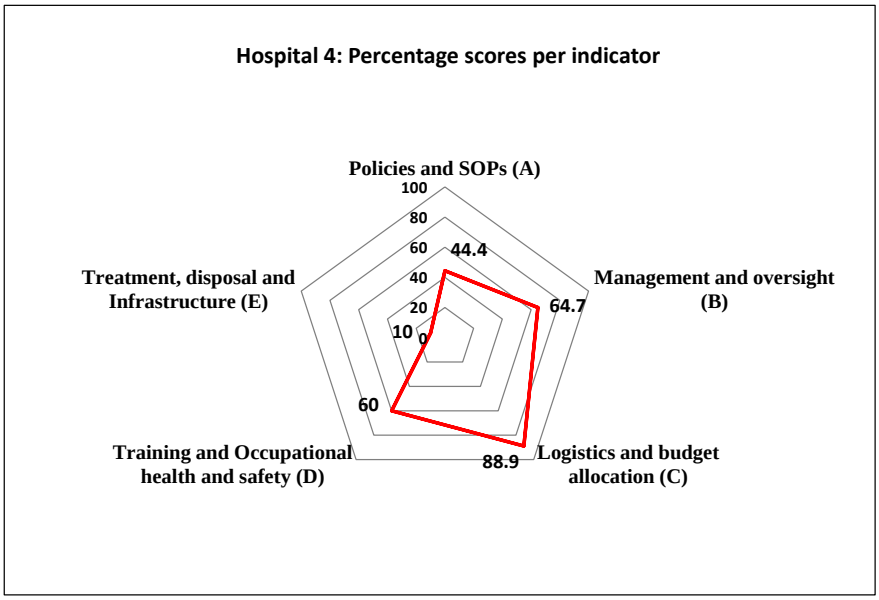

Figure 4. HCWM system assessed in hospital 4.

Hospital 3 had a fair level of HCWM system with an overall score of 53.56% (Table 9), ranking of 1 (Table 1). This hospital had indicator scores ranging from 40% in indicator D to 70.6% in indicator B. Hospital 4 had an overall score of 53.6%, ranked as 2 and interpreted as fair with score ranging from 10% in indicator E to 88.9% for indicator C (Table 9). Hospital 5 had an overall score of 41.06% ranked as 1 and interpreted as poor in HCWM systems. This hospital had scores ranging from 10% for indicator E to 55.6% for indicator C (Table 9).

Hospital 3 scored fairly (55.5%) in indicator A while the rest of the hospitals scored poorly (<50%). Hospital 3 and 4 scored fairly in indicator B with 70.6% and 64.7% while other hospitals scored poorly. Hospital 1 and 4 were rated good

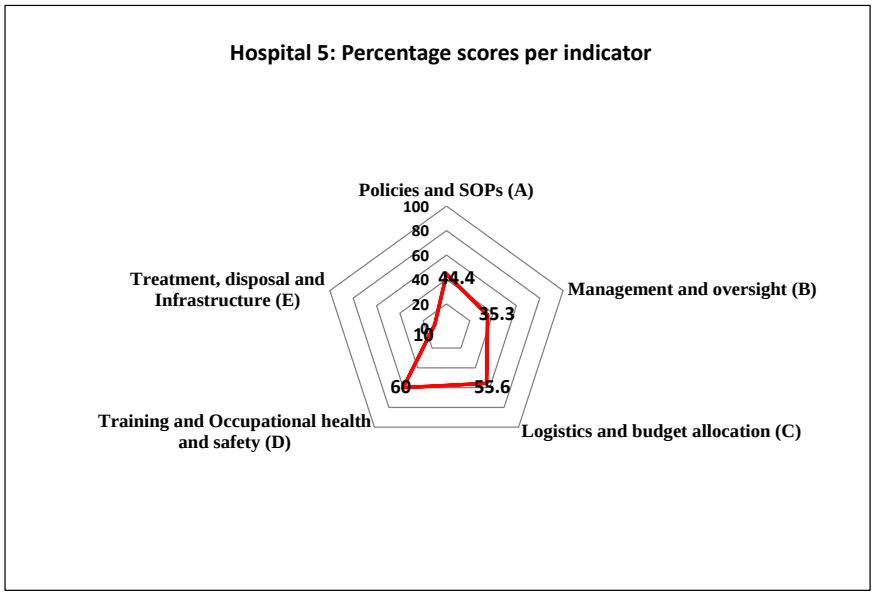

Figure 5. HWM system assessed in hospital 5.

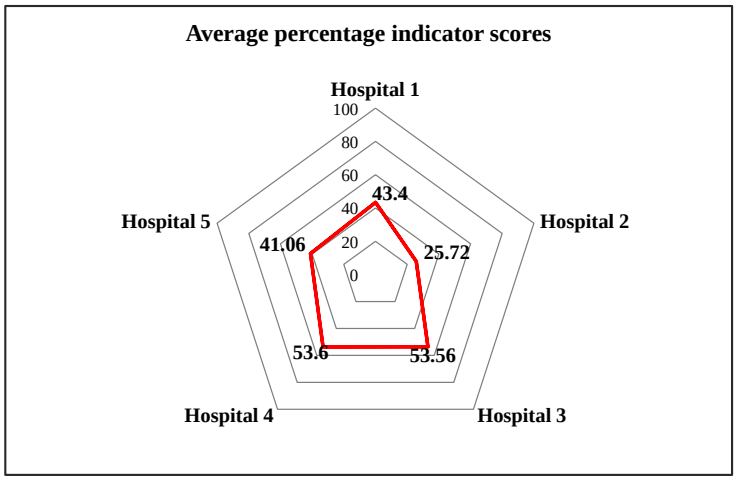

Figure 6. Average indicator scores per hospital.

in indicator C with 77.8% and 88.7% respectively while hospital 3 and 5 were rated to be fair. Hospital 2 was poor in indicator C with score of 44.4%. Hospital 4 and 5 were rated fair in indicator D with a score of 60% each, while the rest of the hospitals were poor with a score of <50%. All the hospitals assessed scored poorly in indicator E (Table 9).

Hospital 2 scored poorly in all the indicators according to the criteria set (Table 1) with scores ranging from 5% for the indicator on treatment, disposal and infrastructure to 44.4% (Table 8) for the indicator on logistics and budget support (Figure 2).

Hospital 3 scored 40% for training and occupational health indicator and 45% (Table 8) for treatment, disposal and infrastructure, a ranking of 1 which was interpreted as poor while this hospital scored between 50% - 74% which was interpreted a fair (Table 1) level of HCWM (Figure 3).

Hospital 4 scored the poorest (10%) in the area of HCWM treatment, treatment equipment management, disposal and infrastructure. The hospital was also poor in the area of policies and standard operating procedures and scored 44.4%, (Table 8) a ranking of 1 and interpreted as poor (Table 1). However, this hospital was good (88.9%), a ranking of 3, in the area of planning for HCWM logistics and providing the necessary budget support. Management and oversight, and training and occupational health and safety scored fairly with scores of 64.7% and 60% respectively (Figure 4).

Hospital 5 also had the lowest score in the area of HCW treatment, disposal and infrastructure (10%), ranking score of 1 and interpreted as poor (Table 1). Policies and SOPs, and management and oversight indicators were also rated poor with scores below 50%. Indicators of logistics and budget support for HCWM, and HCWM training and occupational health and safety scored fairly (Table 1) with scores of 55.6% and 60% (Table 8) respectively (Figure 5).

Figure 6 presents the average indicator scores form each hospital when all the scores for all the indicators were added together. Hospitals 1, 2 and 5 scored below 50% which was ranked as 1 and interpreted as having a poor level of HCWM. Hospitals 3 and 4 scored in between 50% and 74%, (Table 8) which has a ranking score of 2 and interpreted as a fair level of HCWM. The hospitals can be ranked from highest to lowest level of HCWM as follows; Hospital 4, 3, 1, 5 and 2.

5. Discussion

Main goal of the study was to develop and apply a management tool for HCW management systems from generation to disposal in five county hospitals in Kenya. Key insights as concerns performance indicators for HCW management systems include the variety and diversity of successful models—there is no "one size fits all"; the necessity of good, reliable data; the importance of focusing on governance as well as technology; and the need to build on the existing strengths [76]. This study developed integrated indicators sought to be most relevant to developing countries and which are consistent with various studies [1]-[6] [25] [74] [76] in this area. The five management indicators were developed and applied to assess HCWM systems using a predetermined ranking scale in the five county hospitals. These indicators included policies and standard operating procedures, management and oversight structures, logistics and budget support, Training and Occupational Health and safety, and treatment, disposal and infrastructure. The scores obtained were used to rank the county hospitals' HCW management systems as poor (0% - 49%), fair (50% - 74%) or good (74% and above).

5.1. Policy and Standard Operating Procedures

HCWM in Kenya can be considered poor due to inadequate national policy dissemination to the county level and consequently affecting development of spe-

cific standard operating procedures, lack of development of management and oversight structures in hospitals poor treatment and disposal infrastructure. However, the five hospitals studied in Kenya could be considered a good example regarding provision and use of HCWM commodities that facilitate provision of PPEs for handling HCW during segregation of waste at generation points, collection, transportation, treatment and final disposal. Further, it's still a good example in training of healthcare workers, waste handlers and incinerator operators on HCWM and infection prevention and control to ensure safety to human health and the environment as compared with other developing cities [2] [77] [78]. The lack of national policy dissemination, inadequate development of HCWM and IPC management and oversight structures, and environmental friendly on-site treatment plants, are the main barriers for implementing sustainable HCWM systems in Kenya. Some of the policy documents found to be in place at the National level in Kenya included Environmental Management and coordination Act [79]; Environmental Management and Coordination (Waste Management) regulations [80]; National HCWM strategic plan, 2015-2020, [81]; National HCWM Implementation plan, 2016-2021, [82] and Kenya National Guideline for Safe Management of HCW, [83]. While this study found that Kenya has developed requisite policy and guidelines at the national level, several other studies have found lack of clear policies and legislation from governments of Cameroon [49], Haiti, [84], and Iran [85] and attributed non treatment of hazardous waste and anatomical waste being left undisposed to lack of clear policies and legislation from government bodies. The findings indicate that the current management of HCW is not capable of adequately preserving public health and may cause environmental contamination and infection. This finding agrees with [86] who concluded the same from their systematic review on health and environmental impact of hospital wastes. This study agrees with the recommendation made by [77], that the quantities of HCW generation and consequently requirements for its disposal are increasing.

5.2. Management and Oversight Structures for HCWM and IPC

The study revealed that only 2 (40%) of the hospitals studied were rated fairly while the rest were poor in having put in place management and oversight structures for HCWM and IPC. that lack of IPC committees affected resource allocation to facilitate management of HCW and also hindered accessibility and establishment of reliable HCWM plans and Standard Operating Procedures. This is in agreement with [87] in their study in Nigeria which found that the activities of waste managers in HCW facilities are rarely subjected to administrative scrutiny or supervision.

This finding concurs with a qualitative rapid assessment of Infection Prevention and Control (IPC) practices in twelve HCW facilities in five provinces which revealed significant differences which were attributable to the presence or absence of Infection Prevention and Control Committee (IPCC) and an IPC lead

person [88]. Another finding which concurs with our study was that presence of sharps containers, waste bins, incinerators, and personal protective equipment (PPE) did not necessarily lead to their correct use in the absence of functional IPCCs and active IPC lead persons who acted as catalysts, trainers, and role models [88].

5.3. Logistics and Budget Support

All the five hospitals studied had practiced segregation, used the recommended color codes, color coded bins and liners and sharps containers were available at service delivery points during the time of study. This may have been contributed to by low knowledge on HCW segregation practices. These finding agree with another study in Nigeria, which found that poor or no training of healthcare workers on the management of HCW can be a pointer to poor funding available in the country for health sector in the country [89]. However, all the hospitals in this Kenyan study had a challenge in provision of dedicated trolleys to transport HCW from generation points to the treatment sites which may be due to lack of dedicated budgets. In two (40%) out of five hospitals, waste segregation was not done according to guidelines provided, sharps containers were not positioned at arm's length and coded bins not matched with bin liners. A study done in Nigeria reported that non adherence to HCW management guidelines was as a result of absence of specific budgets and financial allocations to cater for waste management within hospitals [90]. Majority (80%) of the hospitals in this study indicated that lack of adequate waste bins and liners was the greatest challenge that hindered waste segregation.

This is in agreement with a study on HCW management carried out in Ethiopia which noted that there was a general lack of basic knowledge of HCW solutions and segregation was not practiced [28]. Further, it is reported in Malaysia that even after provision of a HCW policy and training of healthcare workers, poor waste segregation continued in the healthcare facilities because of the absence of tools required for the segregation [91].

5.4. Training and Occupational Safety and Health of Healthcare Workers, Waste Handlers and Incinerator Operators

This study established that all the five hospitals appraised had all their waste handlers wearing PPEs that were in good condition, had a sharp injury surveillance system in place, needle stick and incidents documented in a logbook register, employees were knowledgeable of post exposure prophylaxis (PEP) procedures and that PEP was available to staff for twenty-four hours a day. This is contrary to a study done in Nigeria that found that majority of workers handling waste without working tools and infection control materials, which exposed them to infection [92]. The disagreement could be due to the fact that we studied all the health workers while they studied only the dental workers. It was only in one out of four hospitals (hospital 4) that incinerator operators used all recommended PPEs (heavy duty gloves, boots covering feet, overalls or aprons, face

masks, eye goggles and respirators while waste handlers in hospital 1 used none of the PPEs while handling HCW. Only hospital 1 had IPC training documented, induction training on HCWM done to new employees and documented; and had trained more than sixty healthcare workers. This may be the reason only 5 had needle stick injuries in one year out of 26,419 outpatient attendants.

The study concurs with another study that emphasized training of healthcare workers, waste handlers and incinerator operators to equip them with knowledge in handling of HCW to ensure safety measures are observed and protects them from the risk of infection that would emanate from handling of HCW [93].

5.5. Treatment, Disposal and Housing of HCW Treatment Equipment

Incineration was the technology used in the five county hospitals studied as a HCW treatment method. This concurs with the findings of a study done in Portugal where they found similar results [94]. This study found that although there was segregation being practiced at the point of HCW generation, general, infectious, highly infectious waste and sharps all ended up in the treatment facility. This finding concurs with that of another study in Botswana which concluded that due to lack of formal training, non-clinical waste was often transported for unnecessary internal incineration with hazardous clinical waste leading to over-crowding, overuse and overwhelming of staff and incinerator [95].

In this study, type of incinerator, functionality of incinerator, provision of temperature regulation device and its functionality, existence of standard operating procedures for the waste treatment facility, availability of equipment manufacturer's operators manuals, readily available equipment spare parts, preventive maintenance logbook for the local biomedical engineers or a proof of a service contract for the equipment, presence of backup procedures in case of equipment failure and that waste treatment equipment that was in use posed no harm to incinerator operators, local community and the environment were important issues studied. On-site incineration of HCW was favored in the five hospitals studied. This is because it is seen as fast and cost-effective, but its thoroughness attracts speculations and major concerns relating to design, operation and maintenance. All the hospitals visited used a de-montfort type of incinerator which had no temperature monitoring gauges except hospital 3, which had a diesel fired incinerator. It has been recommended that low temperature incinerators should be banned if incineration was seen as the solution to HCW treatment [85]. However, hospital 3 incinerator though a more recent technology lacked pollution control devices for cleaning gaseous emissions from HCW incineration. All the incinerators assessed did not meet the national guidelines for waste management as set standards by the National Environment Management Authority, 2006.

A study on Environmental impacts of the US concluded that, pollution is the greatest environmental cause of disease and premature death around the globe and the healthcare sector has been noted for being a significant contributor to

acid rain, greenhouse gas emissions, air pollutants, stratospheric ozone depletion and carcinogenic air toxics [96]. Further, other studies found that pollutants such as carbon monoxide, nitrogen oxides and Sulphur dioxide from HCW treatment led to global warming and as such many related diseases have affected global populations and that global warming has also led to the emergence of numerous parasitic diseases often in parts of the world never previously seen [97] [98].

5.6. Potentiality of the HWM Indicators

The HCWM management indicators introduced in this article allowed HCWM system to be compared among five hospitals in Kenya. Moreover, through the comparison with the data quality, the indicators can be assessed in terms of their reliability. The indicators and the methodology applied can be useful for providing suggestions to local hospitals' stakeholders and policy-makers both at national and county governments on improvements required for obtaining the highest score and for taking into account management issues that have not been considered. The indicators presented in this article can be used to monitor and track improvements in HCWM systems, compare hospitals and for providing benchmark for baseline that can be used by the management internally or by an external evaluator. Therefore, the indicator set can be a tool for contributing to the improvement of the awareness about HCWM issues and management requirements for boosting sustainability and health at a global level. This method will require to be applied in other case studies in Kenya, in order to compare other realities in terms of quality of the HCWM system. The results of the application of this management tool will provide suggestions about which specific criterion requires to be prioritized in an indicator leading to improvement in waste segregation, storage, collection, treatment and final disposal. spreading the awareness about health risks and introducing new options regarding prevention and monitoring systems.

5.7. Study Limitations and Future Improvements

The research conducted in Kenya was implemented only in five hospitals which only provides a minimal indication of the Kenyan HCWM system. Therefore, it is suggested that the tool be applied in more hospitals and that the indicators should be continually improved. Moreover, the indicators were implemented only in Coast, Eastern, Rift Valley regions in Kenya while more research should be done in all regions to assess if there would be differences and whether the indicators can be applied in all levels of hospitals. The approach was not replicated in other countries. The research should be repeated in other contexts with different regulations and social behaviour, in order to assess the reliability of the indicators for other case studies. The generation rates for the hospitals assessed were not included since this data was missing. The last limitation of the study is its implementation over a limited period. The indicators should be implemented

in a hospital as a baseline, all HCWM actors in a hospital should then be trained and equipped with necessary tools and reassessed after implementing HCWM for a period of time in order to provide a dynamic view of the HCWM system implemented at hospital.

6. Conclusions and Recommendations

1) The approach presented in this article can be considered a contribution towards development and application of a management tool for planning, monitoring and tracking HCWM systems in developing countries, in agreement with the suggestions provided by WHO.

2) The indicators suggested can be considered as a decision support tool for assessing and comparing the current HCWM system in hospitals in low-middle income countries, since the availability of a list of management requirements, as well as a method for classifying the main weak points that require prioritization for improvement, can be useful for planning appropriate training, provision of appropriate PPEs, storage, collection, transportation, treatment and disposal systems by governments, authorities and hospitals.

3) This study is a useful starting point for introducing the methodology provided, which can be applied in assessing and monitoring hospitals' HCWM systems in other developing countries worldwide and help guide policy makers into needy areas of HCW management that would require improvement to prevent nosocomial infections.

4) Studies related to the background of HCWM systems are important for assessing the best future scenarios.

5) The objective is to assess the main weak points of each study area in terms of availability and use of HCWM policies and standard operating procedures, putting in place management and oversight structures for HCWM and IPC, mobilizing HCWM logistics and requisite budget support, ensuring that all healthcare workers, waste handlers and incinerator operators are trained for occupational safety and that the hospital is equipped with HCWM treatment and disposal facilities.

6) This study is a contribution as regards the investigation of HCWM systems in Kenya, and the introduction of management tools useful for understanding current storage, collection, transportation, treatment and final disposal practices in this context.

7) HCWM in Kenya represents an issue that should be investigated, in particular as regards appropriate treatment technologies.

8) The evaluation team using this assessment tool should undertake deliberate weighing of wastes delivered at the incinerator to assist in calculation of wastes generated per bed per day.

Acknowledgements

The authors wish to acknowledge the support given by health managers from the

sampled county hospitals who included, healthcare workers, infection prevention and control coordinators, medical superintendents, hospital administrators and public health officers.

Future Research

This would include assessment of microbiological and chemical environmental contamination and emissions produced during treatment and final disposal of HCW.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Mol, M.P., Gonçalves, J.P., Silva, E.A., Scarponi, F.D.O., Greco, D.B., Cairncross, S. and Heller, L. (2016) Seroprevalence of Hepatitis B and C among Domestic and Healthcare Waste Handlers in Belo Horizonte, Brazil. *Waste Management & Research*, **34**, 875-883. https://doi.org/10.1177/0734242X16649686

[2] Ali, M., Wang, W., Chaudhry, N. and, Geng, Y. (2017) Hospital Waste Management in Developing Countries: A Mini Review. *Waste Management & Research*, **35**, 581-592. https://doi.org/10.1177/0734242X17691344

[3] Koolivand, A., Mahvi, A.H., Alipoor, V., Azizi, K. and Binavapour, M. (2012) Investigating Composition and Production Rate of Healthcare Waste and Associated Management Practices in Bandar Abbass, Iran. *Waste Management & Research*, **30**, 601-606. https://doi.org/10.1177/0734242X11416037

[4] Haylamicheal, I.D., Dalvie, M.A., Yirsaw, B.D. and Zegeye, H.A. (2011) Assessing the Management of Healthcare Waste in Hawassa City, Ethiopia. *Waste Management & Research*, **29**, 854-862. https://doi.org/10.1177/0734242X10379496

[5] De Titto, E., Savino, A.A. and Townend, W.K. (2012) Healthcare Waste Management: The Current Issues in Developing Countries. *Waste Management & Research*, **30**, 559-561. https://doi.org/10.1177/0734242X12447999

[6] Akpieyi, A., Tudor, T.L. and Dutra, C. (2015) The Utilization of Risk-Based Frame Works for Managing Healthcare Waste: A Case Study of the National Health Service in London. *Safety Science*, **72**, 127-132. https://doi.org/10.1016/j.ssci.2014.08.014

[7] Minoglou, M., Gerassimidou, S. and Komilis, D. (2017) Healthcare Waste Generation Worldwide and Its Dependence on Socio-Economic and Environmental Factors. *Sustainability*, **9**, Article 220. https://doi.org/10.3390/su9020220

[8] Ferreira, J.A., Bila, D.M., Ritter, E. and Braga, A.C.S. (2012) Chemical Healthcare waste Management in Small Brazilian Municipalities. *Waste Management & Research*, **30**, 1306-1311. https://doi.org/10.1177/0734242X12459551

[9] Mmanga, M., Singini, W., Di Bella, V., Flaherty, M.G. and Holm, R.H. (2019) Unpacking Healthcare Waste Management at Rural Village Health Clinics in the Ntcheu District (Malawi). *Environmental Monitoring and Assessment*, **191**, Article No. 175. https://doi.org/10.1007/s10661-019-7306-6

[10] Windfeld, E.S. and Brooks, M.S.L. (2015) Medical Waste Management: A Review. *Journal of Environmental Management*, **163**, 98-108.

https://doi.org/10.1016/j.jenvman.2015.08.013

[11] Chaerul, M., Tanaka, M. and Shekdar, A.V. (2008) A System Dynamics Approach for Hospital Waste Management. *Waste Management*, **28**, 442-449. https://doi.org/10.1016/j.wasman.2007.01.007

[12] Elimelech, E., Ayalon, O. and Flicstein, B. (2011) Hazardous Waste Management and Weight-Based Indicators: The Case of Haifa Metropolis. *Journal of Hazardous Materials*, **185**, 626-633. https://doi.org/10.1016/j.jhazmat.2010.09.064

[13] Diaz, L.F., Eggerth, L.L., Enkhtsetseg, S.H. and Savage, G.M. (2008) Characteristics of Healthcare Wastes. *Waste Management*, **28**, 1219-1226. https://doi.org/10.1016/j.wasman.2012.09.018

[14] Maamari, O., Brandam, C., Lteif, R. and Salameh, D. (2015) Health Care Waste Generation Rates and Patterns: The Case of Lebanon. *Waste Management*, **43**, 550-554. https://doi.org/10.1016/j.wasman.2015.05.005

[15] Sartaj, M. and Arabgol, R. (2015) Assessment of Healthcare Waste Management Practices and Associated Problems in Isfahan Province (Iran). *Journal of Material Cycles and Waste Management*, **17**, 99-106. https://doi.org/10.1007/s10163-014-0230-5

[16] Ferronato, N. and Torretta, V. (2019) Waste Mismanagement in Developing Countries: A Review of Global Issues. *International Journal of Environmental Research and Public Health*, **16**, Article 1060. https://doi.org/10.3390/ijerph16061060

[17] Barbosa, F.C.L. and Mol, M.P.G. (2018) Proposal of Indicators for Health Care Waste Management: Case of a Brazilian Public Institution. *Waste Management & Research*, **36**, 934-941. https://doi.org/10.1177/0734242X18777797

[18] Ananth, A.P., Prashanthini, V. and Visvanathan, C. (2010) Healthcare Waste Management in Asia. *Waste Management*, **30**, 154-161. https://doi.org/10.1016/j.wasman.2009.07.018

[19] Tesfahun, E., Kumie, A. and Beyene, A. (2016) Developing Models for the Prediction of Hospital Healthcare Waste Generation Rate. *Waste Management & Research*, **34**, 75-80. https://doi.org/10.1177/0734242X15607422

[20] Moreira, A.M.M. and Günther, W.M.R. (2013) Assessment of Medical Waste Management at a Primary Health-Care Center in São Paulo, Brazil. *Waste Management*, **33**, 162-167. https://doi.org/10.1016/j.wasman.2012.09.018

[21] Caniato, M., Tudor, T. and Vaccari, M. (2015) International Governance Structures for Health-Care Waste Management: A Systematic Review of Scientific Literature. *Journal of Environmental Management*, **153**, 93-107. https://doi.org/10.1016/j.jenvman.2015.01.039

[22] Lee, S., Vaccari, M. and Tudor, T. (2016) Considerations for Choosing Appropriate Healthcare Waste Management Treatment Technologies: A Case Study from an East Midlands NHS Trust, in England. *Journal of Cleaner Production*, **135**, 139-147. https://doi.org/10.1016/j.jclepro.2016.05.166

[23] Geng, Y., Ren, W.X., Xue, B., Fujita, T., Xi, F., Liu, Y. and Wang, M. (2013) Regional Medical Waste Management in China: A Case Study of Shenyang. *Journal of Material Cycles and Waste Management*, **15**, 310-320. https://doi.org/10.1007/s10163-013-0118-9

[24] Thakur, V. and Ramesh, A. (2015) Healthcare Waste Management Research: A Structured Analysis and Review (2005-2014). *Waste Management & Research*, **33**, 855-870. https://doi.org/10.1177/0734242X15594248

[25] World Health Organization (2014) Safe Management of Wastes from Health-Care Activities.

http://www.searo.who.int/srilanka/documents/safe_management_of_wastes_from_healthcare_activities. pdf?ua=1

[26] Caniato, M., Tudor, T.L. and Vaccari, M. (2016) Assessment of Health-Care Waste Management in a Humanitarian Crisis: A Case Study of the Gaza Strip. *Waste Management*, **58**, 386-396. https://doi.org/10.1016/j.wasman.2016.09.017

[27] El-Salam, M.M.A. (2010) Hospital Waste Management in El-Beheira Governorate, Egypt. *Journal of Environmental Management*, **91**, 618-629. https://doi.org/10.1016/j.jenvman.2009.08.012

[28] Yazie, T.D., Tebeje, M.G. and Chufa, K.A. (2019) Healthcare Waste Management Current Status and Potential Challenges in Ethiopia: A Systematic Review. *BMC Research Notes*, **12**, Article No. 285. https://doi.org/10.1186/s13104-019-4316-y

[29] Hasan, M.M. and Rahman, M.H. (2018) Assessment of Healthcare Waste Management Paradigms and Its Suitable Treatment Alternative: A Case Study. *Journal of Environmental and Public Health*, **2018**, Article ID: 6879751. https://doi.org/10.1155/2018/6879751

[30] Dehghani, M.H., Ahrami, H.D., Nabizadeh, R., Heidarinejad, Z. and Zarei, A. (2019) Medical Waste Generation and Management in Medical Clinics in South of Iran. *MethodsX*, **6**, 727-733. https://doi.org/10.1016/j.mex.2019.03.029

[31] Taslimi, M., Batta, R. and Kwon, C. (2020) Medical Waste Collection Considering Transportation and Storage Risk. *Computers & Operations Research*, **120**, Article 104966. https://doi.org/10.1016/j.cor.2020.104966

[32] Chartier, Y. and World Health Organization (2014) Safe Management of Wastes from Health-Care Activities. World Health Organization, Geneva.

[33] Olaifa, A., Govender, R.D. and Ross, A.J. (2018) Knowledge, Attitudes and Practices of Healthcare Workers about Healthcare Waste Management at a District Hospital in Kwazulu-Natal. *South African Family Practice*, **60**, 137-145. https://doi.org/10.1080/20786190.2018.1432137

[34] Meleko, A., Tesfaye, T. and Henok, A. (2018) Assessment of Healthcare Waste Generation Rate and Its Management System in Health Centers of Bench Maji Zone. *Ethiopian Journal of Health Sciences*, **28**, 125-134. https://doi.org/10.4314/ejhs.v28i2.4

[35] Khan, B.A., Cheng, L., Khan, A.A. and Ahmed, H. (2019) Healthcare Waste Management in Asian Developing Countries: A Mini Review. *Waste Management & Research*, **37**, 863-875. https://doi.org/10.1177/0734242X19857470

[36] Ciplak, N. and Kaskun, S. (2015) Healthcare Waste Management Practice in the West Black Sea Region, Turkey: A Comparative Analysis with the Developed and Developing Countries. *Journal of the Air & Waste Management Association*, **65**, 1387-1394. https://doi.org/10.1080/10962247.2015.1076539

[37] Kwikiriza, S., Stewart, A.G., Mutahunga, B., Dobson, A.E. and Wilkinson, E. (2019) A Whole Systems Approach to Hospital Waste Management in Rural Uganda. *Frontiers in Public Health*, **7**, Article 136. https://doi.org/10.3389/fpubh.2019.00136

[38] Santos, E.D.S., Gonçalves, K.M.D.S. and Mol, M.P.G. (2018) Healthcare Waste Management in a Brazilian University Public Hospital. *Waste Management & Research*, **37**, 278-286. https://doi.org/10.1177/0734242X18815949

[39] Kalogiannidou, K., Nikolakopoulou, E. and Komilis, D. (2018) Generation and Composition of Waste from Medical Histopathology Laboratories. *Waste Management*, **79**, 435-442. https://doi.org/10.1016/j.wasman.2018.08.012

[40] Xin, Y. (2015) Comparison of Hospital Medical Waste Generation Rate Based on Diagnosis-Related Groups. *Journal of Cleaner Production*, **100**, 202-207.

https://doi.org/10.1016/j.jclepro.2015.03.056

[41] Arab, M., Baghbani, R.A., Tajvar, M., Pourreza, A., Omrani, G. and Mahmoudi, M. (2008) Report: The Assessment of Hospital Waste Management: A Case Study in Tehran. *Waste Management & Research*, **26**, 304-308. https://doi.org/10.1177/0734242X08093598

[42] Wafula, S.T., Musiime, J. and Oporia, F. (2019) Health Care Waste Management among Health Workers and Associated Factors in Primary Health Care Facilities in Kampala City, Uganda: A Cross-Sectional Study. *BMC Public Health*, **19**, Article No. 203. https://doi.org/10.1186/s12889-019-6528-4

[43] Sahiledengle, B. (2019) Self-Reported Healthcare Waste Segregation Practice and Its Correlate among Healthcare Workers in Hospitals of Southeast Ethiopia. *BMC Health Services Research*, **19**, Article No. 591. https://doi.org/10.1186/s12913-019-4439-9

[44] Awodele, O., Adewoye, A.A. and Oparah, A.C. (2016) Assessment of Medical Waste Management in Seven Hospitals in Lagos, Nigeria. *BMC Public Health*, **16**, Article 269. https://doi.org/10.1186/s12889-016-2916-1

[45] Parida, A., Capoor, M.R. and Bhowmik, K.T. (2019) Knowledge, Attitude, and Practices of Bio-Medical Waste Management Rules, 2016; Bio-Medical Waste Management (Amendment) Rules, 2018; and Solid Waste Rules, 2016, among Health-Care Workers in a Tertiary Care Setup. *Journal of Laboratory Physicians*, **11**, 292-299. https://doi.org/10.4103/JLP.JLP_88_19

[46] Datta, P., Mohi, G.K. and Chander, J. (2018) Biomedical Waste Management in India: Critical Appraisal. *Journal of Laboratory Physicians*, **10**, 6-14. https://doi.org/10.4103/JLP.JLP_89_17

[47] Hadipour, M., Saffarian, S., Shafiee, M. and Tahmasebi, S. (2014) Measurement and Management of Hospital Waste in Southern Iran: A Case Study. *Journal of Material Cycles and Waste Management*, **16**, 747-752. https://doi.org/10.1007/s10163-013-0214-x

[48] Cesaro, A. and Belgiorno, V. (2017) Sustainability of Medical Waste Management in Different Sized Health Care Facilities. *Waste and Biomass Valorization*, **8**, 1819-1827. https://doi.org/10.1007/s12649-016-9730-y

[49] Manga, V.E., Forton, O.T., Mofor, L.A. and Woodard, R. (2011) Health Care Waste Management in Cameroon: A Case Study from the South-Western Region. *Resources, Conservation and Recycling*, **57**, 108-116. https://doi.org/10.1016/j.resconrec.2011.10.002

[50] Farzadkia, M., Moradi, A., Mohammadi, M.S. and Jorfi, S. (2009) Hospital Waste Management Status in Iran: A Case Study in the Teaching Hospitals of Iran University of Medical Sciences. *Waste Management & Research*, **27**, 384-389. https://doi.org/10.1177/0734242X09335703

[51] Sasu, S., Kümmerer, K. and Kranert, M. (2012) Assessment of Pharmaceutical Waste Management at Selected Hospitals and Homes in Ghana. *Waste Management & Research*, **30**, 625-630. https://doi.org/10.1177/0734242X11423286

[52] Khammaneechan, P., Okanurak, K., Sithisarankul, P., Tantrakarnapa, K. and Norramit, P. (2011) Effects of an Incinerator Project on a Healthcare-Waste Management System. *Waste Management & Research*, **29**, S91-S96. https://doi.org/10.1177/0734242X11411013

[53] World Health Organization (2017) Safe Management of Wastes from Health-Care Activities: A Summary. World Health Organization, Geneva.

[54] Singh, H., Rehman, R. and Bumb, S. (2014) Management of Biomedical Waste: A

Review. *International Journal of Dental and Medical Research*, **1**, 14-20.

[55] Njagi, N.A., Oloo, M.A., Kithinji, J. and Kithinji M.J. (2012) Health-Care Waste Incineration and Related Dangers to Public Health: Case Study of the Two Teaching and Referral Hospitals in Kenya. *Journal of Community Health*, **37**, 1168-1171. https://doi.org/10.1007/s10900-012-9578-4

[56] Padmanabhan, K.K. and Barik, D. (2019) Health Hazards of Medical Waste and Its Disposal. In: Barik, D., Ed., *Energy from Toxic Organic Waste for Heat and Power Generation*, Woodhead Publishing, Cambridge, 99-118. https://doi.org/10.1016/B978-0-08-102528-4.00008-0

[57] De Titto, E. and Savino, A. (2019) Environmental and Health Risks Related to Waste Incineration. *Waste Management & Research*, **37**, 976-986. https://doi.org/10.1177/0734242X19859700

[58] Santoro, M., Minichilli, F., Linzalone, N., Coi, A., Maurello, M.T., Sallese, D. and Bianchi, F. (2016) Adverse Reproductive Outcomes Associated with Exposure to a Municipal Solid Waste Incinerator. *Annali dell'Istituto Superiore di Sanita*, **52**, 576-581.

[59] Domingo, J.L., Marquès, M., Mari, M. and Schuhmacher, M. (2020) Adverse Health Effects for Populations Living Near Waste Incinerators with Special Attention to Hazardous Waste Incinerators. A Review of the Scientific Literature. *Environmental Research*, **187**, Article 109631. https://doi.org/10.1016/j.envres.2020.109631

[60] Saria, J.A. (2016) Levels of Heavy Metals in Bottom Ash from Medical Waste Incinerators in Dares Salaam. *Journal of Multidisciplinary Engineering Science Studies*, **2**, 599-605.

[61] Udofia, E.A., Gulis, G. and Fobil, J. (2017) Solid Medical Waste: A Cross Sectional Study of Household Disposal Practices and Reported Harm in Southern Ghana. *BMC Public Health*, **17**, Article No. 464. https://doi.org/10.1186/s12889-017-4366-9

[62] Dash, A., Kumar, S. and Singh, R.K. (2015) Thermolysis of Medical Waste (Waste Syringe) to Liquid Fuel Using Semi Batch Reactor. *Waste and Biomass Valorization*, **6**, 507-514. https://doi.org/10.1007/s12649-015-9382-3

[63] Fang, S., Jiang, L., Li, P., Bai, J. and Chang, C. (2020) Study on Pyrolysis Products Characteristics of Medical Waste and Fractional Condensation of the Pyrolysis Oil. *Energy*, **195**, Article 116969. https://doi.org/10.1016/j.energy.2020.116969

[64] Hossain, M.S., Santhanam, A., Norulaini, N.N. and Omar, A.K.M. (2011) Clinical Solid Waste Management Practices and Its Impact on Human Health and Environment: A Review. *Waste Management*, **31**, 754-766. https://doi.org/10.1016/j.wasman.2010.11.008

[65] Borowy, I. (2020) Medical Waste: The Dark Side of Healthcare. *História, Ciências, Saúde-Manguinhos*, **27**, 231-251. https://doi.org/10.1590/s0104-59702020000300012

[66] Aung, T.S., Luan, S. and Xu, Q. (2019) Application of Multi-Criteria-Decision Approach for the Analysis of Medical Waste Management Systems in Myanmar. *Journal of Cleaner Production*, **222**, 733-745. https://doi.org/10.1016/j.jclepro.2019.03.049

[67] Woolridge, A. and Hoboy, S. (2019) Chapter 27—Medical Waste. In: Letcher, T.M. and Vallero, D.A., Eds., *Waste*, 2nd Edition, Academic Press, Cambridge, 517-530. https://doi.org/10.1016/B978-0-12-815060-3.00027-X

[68] Babanyara, Y.Y., Aliyu, A., Gana, B.A. and Musa, M. (2020) A Review of the Knowledge, Attitude, and Practices of Healthcare Wastes Workers (HCWS) on Medical Waste in Developing Countries. In: Marfe, G. and Di Stefano, C., Eds., *Risks and Challenges of Hazardous Waste Management: Reviews and Case Studies*, Bentham

Science Publishers, Karachi, 25-45. https://doi.org/10.2174/9789811472466120010 1

[69] Janik-Karpinska, E., Brancaleoni, R., Niemcewicz, M., Wojtas, W., Foco, M., Podogrocki, M. and Bijak, M. (2023) Healthcare Waste—A Serious Problem for Global Health. *Healthcare*, **11**, Article 242. https://doi.org/10.3390/healthcare11020242

[70] Doylo, T., Alemayehu, T. and Baraki, N. (2019) Knowledge and Practice of Health Workers about Healthcare Waste Management in Public Health Facilities in Eastern Ethiopia. *Journal of Community Health*, **44**, 284-291. https://doi.org/10.1007/s10900-018-0584-z

[71] Wilson, D.C., Rodic, L., Cowing, M.J., Velis, C.A., Whiteman, A.D., Scheinberg, A., Vilches, R., Masterson, D., Stretz J. and Oelz, B. (2015) 'Wasteaware' Benchmark Indicators for Integrated Sustainable Waste Management in Cities. *Waste Management*, **35**, 329-342. https://doi.org/10.1016/j.wasman.2014.10.006

[72] Bichmann, W., Rifkin, S.B. and Shrestha, M. (1989) Towards the Measurement of Community Participation. *World Health Forum*, **10**, 467-472.

[73] Muriithi, J.G. (2003) Community Participation in Health Development in Nyandarua District, Kenya. Master's Thesis, Kenyatta University, Nairobi. http://irlibrary.ku.ac.ke/handle/123456789/12948

[74] Ferronato, N., Ragazzi, M., Elias, M.S. T., Portillo, M.A.G., Lizarazu, E.G.G. and Torretta, V. (2020) Application of Healthcare Waste Indicators for Assessing Infectious Waste Management in Bolivia. *Waste Management & Research*, **38**, 4-18. https://doi.org/10.1177/0734242X19883690

[75] Nkonge, A.N., Magambo, J.K., Kithinji, J.M., Mayabi, A.O. and Ndwiga, T. (2014) Management of Healthcare Waste in National Teaching and Referral Hospitals in Kenya. *International Journal of Environment and Waste Management*, **14**, 199-209. https://doi.org/10.1504/IJEWM.2014.064087

[76] Wilson, D.C., Rodic, L., Scheinberg, A., Velis, C.A. and Alabaster, G. (2012) Comparative Analysis of Solid Waste Management in 20 Cities. *Waste Management & Research*, **30**, 237-254. https://doi.org/10.1177/0734242X12437569

[77] Niyongabo, E., Jang, Y.C., Kang, D. and Sung, K. (2019) Generation, Management Practices and Rapid Risk Assessment of Solid Medical Wastes: A Case Study in Burundi. *Journal of Material Cycles and Waste Management*, **21**, 950-961. https://doi.org/10.1007/s10163-019-00854-0

[78] Kenny, C. and Priyadarshini, A. (2021) Review of Current Healthcare Waste Management Methods and Their Effect on Global Health. *Healthcare*, **9**, Article 284. https://doi.org/10.3390/healthcare9030284

[79] Government of Kenya (1999) Environmental Management and Coordination Act.

[80] Government of Kenya (2006) Legal Notice No. 121: Environmental Management and Coordination (Waste Management) Regulations.

[81] Ministry of Health, Kenya (2015) Health Care Waste Management Strategic Plan 2015-2020. Nairobi.

[82] Ministry of Health, Kenya (2016) National HCWM Implementation Plan, 2016-2021. Nairobi.

[83] Ministry of Medical Services and Ministry of Public Health and Sanitation, Kenya (2011) National Guideline for Safe Management of Health Care Waste. Nairobi.

[84] Raila, E.M. and Anderson, D.O. (2017) Healthcare Waste Management during Disasters and Its Effects on Climate Change: Lessons from 2010 Earthquake and Cholera Tragedies in Haiti. *Waste Management & Research*, **35**, 236-245. https://doi.org/10.1177/0734242X16682312

[85] Askarian, M., Heidarpoor, P. and Assadian, O. (2010) A Total Quality Management Approach to Healthcare Waste Management in Namazi Hospital, Iran. *Waste Management*, **30**, 2321-2326. https://doi.org/10.1016/j.wasman.2010.06.020

[86] Ghali, H., Cheikh, A.B., Bhiri, S., Bouzgarrou, L., Rejeb, M.B., Gargouri, I. and Latiri, H.S. (2023) Health and Environmental Impact of Hospital Wastes: Systematic Review. *Dubai Medical Journal*, **6**, 67-80. https://doi.org/10.1159/000529432

[87] Anozie, O.B., Lawani, L.O., Eze, J.N., Mamah, E.J., Onoh, R.C., Ogah, E.O., Umezurike, D.A. and Anozie, R.O. (2017) Knowledge, Attitude and Practice of Healthcare Managers to Medical Waste Management and Occupational Safety Practices: Findings from Southeast, Nigeria. *Journal of Clinical and Diagnostic Research*, **11**, IC011-IC04. https://doi.org/10.7860/JCDR/2017/24230.9527

[88] Ministry of Public Health and Sanitation and Ministry of Medical Services, Kenya (2010) National Infection Prevention and Control Policy for Health Care Services in Kenya. Nairobi.

[89] Uzochukwu, B.S.C., Ughasoro, M.D., Etiaba, E., Okwuosa, C., Anvuladu, E. and Onwujekwe, O.E. (2015) Healthcare Financing in Nigeria: Implications for Achieving Universal Health Coverage. *Nigerian Journal of Clinical Practice*, **18**, 437-444. https://doi.org/10.4103/1119-3077.154196

[90] Baaki, T.K., Baharum, M.R. and Akashah, F.W. (2017) Critical Success Factors of Medical Waste Management in Health Care Facilities in Nigeria: A Case Study. *Journal of Design and Built Environment*, **17**, 18-35. https://doi.org/10.22452/jdbe.vol17no1.2

[91] Hamadan, N., Sapri, M., Mohammed, A.H., Awang, M., Rahman, M.S.A., Rosli, N.W. and Lah, N.M. (2012) The Implementation of Clinical Waste Handling in Hospital Sultanah Aminah Johor Bahru (HSAJB). *Procedia*: *Social and Behavioral Sciences*, **65**, 802-807. https://doi.org/10.1016/j.sbspro.2012.11.202

[92] Adedigba, M.A., Nwhator, S.O., Afon, A., Abegunde, A.A. and Bamise, C.T. (2010) Assessment of Dental Waste Management in a Nigerian Tertiary Hospital. *Waste Management & Research*, **28**, 769-777. https://doi.org/10.1177/0734242X09356017

[93] Sagoe, C., Pearson, R.D., Perry, J. and Jagger, J. (2001) Risks to Health Care Workers in Developing Countries. *New England Journal of Medicine*, **345**, 538-540. https://doi.org/10.1056/NEJM200108163450711

[94] Alvim-Ferraz, M.C.M. and Afonso, S.A.V. (2005) Incineration of Healthcare Wastes: Management of Atmospheric Emissions through Waste Segregation. *Waste Management*, **25**, 638-648. https://doi.org/10.1016/j.wasman.2004.07.017

[95] Mbongwe, B., Mmereki, B.T. and Magashula, A. (2008) Healthcare Waste Management: Current Practices in Selected Healthcare Facilities, Botswana. *Waste Management*, **28**, 226-233. https://doi.org/10.1016/j.wasman.2006.12.019

[96] Eckelman, M.J. and Sherman, J. (2016) Environmental Impacts of the U.S. Health Care System and Effects on Public Health. *PLOS ONE*, **11**, e0157014. https://doi.org/10.1371/journal.pone.0157014

[97] Honest, A., Manyele, S., Saria, J. and Mbuna, J. (2020) Assessment of Air Pollutant Emissions from Healthcare Waste Incinerators of Different Design Features. *African Journal of Environmental Science and Technology*, **14**, 311-328.

[98] Manisalidis, I., Stavropoulou, E., Stavropoulou, A. and Bezirtzoglou, E. (2020) Environmental and Health Impacts of Air Pollution: A Review. *Frontiers in Public Health*, **8**, Article 14. https://doi.org/10.3389/fpubh.2020.00014