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Readiness of Healthcare Facilities to Implement Onsite Healthcare Waste Management Protocols and Incineration Guidelines in Tanzania

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Abstract

The aim of this study was to assess Readiness of Healthcare facilities to Implement onsite Healthcare Waste Management Protocols and Incineration Guidelines in Tanzania. To address this, a national assessment was conducted country wide to assess readiness of Healthcare Facilities (HCFs) to undertake various Healthcare Waste Management (HCWM) initiatives with particular focus to adherence to HCWM protocols and incineration guidelines. The assessment of healthcare waste management was conducted in facilities in the 26 regions of Tanzania mainland for one month. A standardized checklist and tools were used to assess and monitor various aspects related to healthcare waste management using open source software for data collection (ODK). Data were analyzed using SPSS computer software. It was observed that 46.2%, 33.3% and 25% of the health centres, district hospitals and regional hospitals did not have appointed supervisors, which makes it difficult for the HCFs to perform better in managing healthcare waste in their respective facilities. It was further revealed that healthcare facilities have made remarkable improvement in the overall healthcare waste management with evidence of ongoing common activity on purchasing injection safety boxes (69.2%) and purchasing of waste bins (53.8%) at all levels. On average, about 70% of the HCFs have plans and budget though inadequate to support HCWM activities. In a conclusion Healthcare Facilities must designate a better system to compressively address healthcare waste management issues. Again the findings provide evidence for those engaged in improving HCF conditions to develop evidence-based policies and efficient programs, enhance service delivery systems, and make better use of available resources.

Keywords

Healthcare Waste, Incinerators, Waste Segregation, Waste Collection, Color Coding, Ash Pits

1. Introduction

Wastes generated in healthcare facilities (HCFs) have the potential to cause harm to the public and to the healthcare workers (HCWs) if not managed properly [1]. The risk originates from waste that may be hazardous due to infectious agents, heavy metals (such as mercury), radioactivity (from oncology treatments), as well as redundant and expired pharmaceuticals [2]. The health risks posed include transmission of diseases such as Human Immunodeficiency Viruses (HIV), Hepatitis B Virus (HBV), Hepatitis C Virus (HCV) contained in the inherent body fluids, accidental Needle Stick Injuries (NSI), and skin and respiratory diseases [3]. Thus proper segregation, collection, onsite transportation and treatment of HCW are critical, covering all aspects or hierarchy of HCW management. Treatment of HCW can be done either onsite or offsite by transporting the collected waste to be treated elsewhere. Most HCFs prefer onsite rather than offsite treatment for safety and control. Public HCFs prefer onsite HCW treatment due to constraints on budget and due to the need for full control of HCW generated [4].

To be able to implement an onsite HCW treatment system, the facility must establish the waste generation rate data to allow proper planning and design of the waste management system [5]. To effectively operate an onsite treatment of the HCW, there are a number of preparatory activities that the HCFs should accomplish, including: ongoing activities for improvements or installation of the onsite treatment facilities, designation of the waste collection staff, waste transportation equipment, designation or construction of the waste storage area, construction and maintenance of the incinerator, fencing of the incinerator area, construction of ash pit and placenta pit, accessibility of the waste treatment area, and provision of PPE. Such accomplishments require waste generation rate data [5].

The method used by many researchers to quantify waste generation rate is by direct measurements. This information can be used to determine the size of the incinerator and the corresponding infrastructure associated with waste collection, transportation and treatment [6] [7]. These studies revealed the need for hospital administrators, and other health stakeholders to give special attention and priority in setting budgets for proper management of healthcare waste in their healthcare facilities. However, none of them focused on preparedness of the HCFs in building the support infrastructure for onsite treatment of HCW.

The management of health-care waste should be an integral part of a national healthcare system. A holistic approach to health-care waste management should include a clear delineation of responsibilities, occupational health and safety programs, waste minimization and segregation, the development and adoption of safe and environmentally-sound technologies, and capacity building [8]. One of the most applicable HCW treatment option in Tanzania is the onsite treatment method, where small scale incinerators are built within the HCF premises. Waste is then collected from different generation points to the storage bay before treatment. For efficient operation of the onsite treatment facility, a number of support infrastructures, management efforts and personnel involvement form the key elements for such a system [7].

Onsite treatment systems may fail due to lack of fuel, lack of spare parts, improper operation, poor segregation of HCW at generation points, poor storage and lack of supportive supervision [6]. Good planning, technical oversight, and sustained supportive supervision of incinerator systems are critical to ensuring safe incineration. Large-capacity, cleaner-burning incinerators usually rely on electricity and fossil fuels to maintain their emission standards [5]. These technologies are often installed in HCFs located in cities and towns where electric power is available. Formulation of objectives and planning for their achievement are important for improving healthcare waste management in the regional, district and Health Center level [4].

Another challenge facing HCFs is carrying out onsite treatment of HCW including lack of support of infrastructure. For the HCW treatment system to operate effectively, there must be properly functioning waste minimization strategies, waste segregation systems (e.g., the color-coded bins in the generation sites), proper waste collection (including staff and transportation equipment), well-functioning waste storage bays, fencing of critical areas, ash pits and placenta pits [8] [9].

The HCF's waste management plan should integrate all aspects of managing waste, from avoidance and minimization, proper segregation and containment, safe handling, storage and transport, to treatment and disposal. It should clearly define roles and responsibilities of staff, guiding principles, as well as the requirements for training and awareness. Reference to the legal requirements, such as those imposed by the government should be made to ensure compliance is established and standards are maintained [9] [10]. This study assessed also the effectiveness in the allocation of resources for HCW management, in terms of finances, execution of planned activities, equipment purchases and use, construction of infrastructure and personnel designation.

Figure 1 shows a simple conceptual diagram portraying the waste generation and onsite treatment. Given the six steps in the waste management hierarchy, the diagram shows the sample waste generation points situated in service areas,

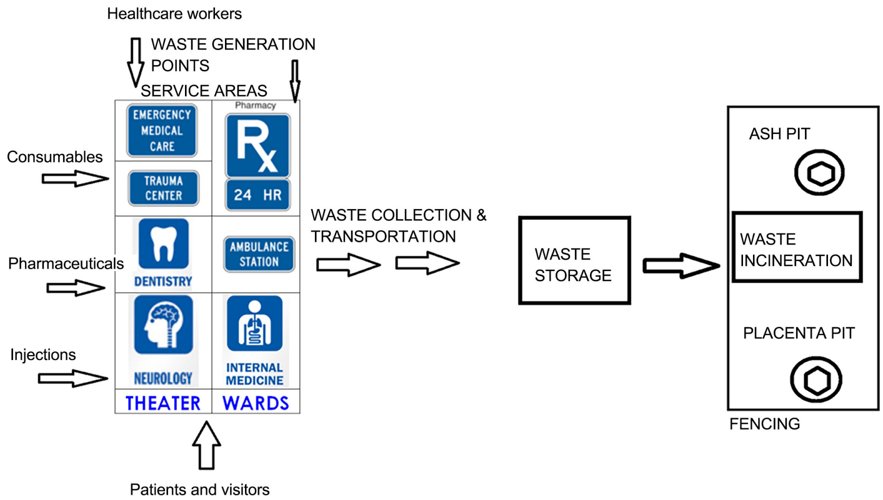


Figure 1. Conceptual diagram of flow of materials into healthcare facility, waste generation in services areas, waste collection, transportation, storage and treatment.

where waste minimization, segregation and colour coding can be applied. The waste collection bins are required to be lined and placed closer to the generation points, all of which must follow the three-bin system (according to selected colour codes), and also, these are areas where the 3/4-full rule can be applied [11]. According to Figure 1, some of the factors contributing to the waste generation rate are number of patients and visitors, flow of materials used in service provision (medical devices, pharmaceuticals, medicines, injection equipment, and other consumables such as reagents).

Once the waste is generated and collected according to the national guidelines, the next step is transportation to the designated storage area, also known as, waste storage bay (WSB). In the latter, the waste must remain segregated as stored until loading into the incinerator combustion chamber. Storage time and temperature should be controlled to avoid waste destruction. As per Figure 1, it is clear that the waste collection bay serves all the health service delivery areas, sizing of which must consider the entire facility. If the waste collection bay is undersized, it will be overwhelmed and the waste management plan will be impaired.

In the treatment area, the most commonly used is the incineration (De Montfort or High-Tech models). There is a need to build an ash pit to accommodate the ash for durations of up to 5 years of incinerator operation, and also the placenta pit, where placentas can be disposed of on daily basis. The High-Tech incinerators, however, can treat placentas, but where the incineration is not done daily, a placenta pit is required. Water and electricity supply to the fenced waste treatment area are essential. For convenience, the waste storage bay should be as closer to the treatment area as possible and can also be within the fenced area.

Thus, this paper focuses on assessing the readiness of the HCFs to support infrastructure based on the national HCW management guidelines of the Ministry of Health [5]. A national survey of health-care waste practices was conducted to cover 26 regions and their constituent districts. A comprehensive survey was essential, covering healthcare waste management, incinerator coverage, WASH, HH, IPC and Environmental Cleaning.

A wide-range of questionnaire was developed by the Ministry of Health in collaboration with higher learning institutions and WHO's country office, and was completed for all health-care establishments in the selected regions in order to establish the following: number of hospital beds and bed occupancy rate for each health-care establishment; types and quantities of waste generated; personnel involved in the management of health-care waste; current health-care waste disposal practices, including segregation, collection, transportation, storage, and disposal methods altogether with the plans and budget allocation to support healthcare waste management [4] [7] [11].

Eliminating potential risks to people's health, healthcare services inevitably create waste that may itself be hazardous to health. The waste produced in the course of healthcare activities carries a higher potential for infection and injury than any other type of waste. Wherever waste is generated, safe and reliable methods for its handling are therefore essential. The aim of this study was to assess readiness of healthcare facilities to implement onsite healthcare waste management protocols and incineration guidelines; and ascertain performance of Healthcare Facilities on safe healthcare waste management practices [10].

1.1. Waste Generation Rate in HCFs

HCW generation rate is a key parameter that determines the success of any onsite option. It tells the size of waste collection containers, size of transportation, workforce, storage bay size and treatment sizing, like primary chamber of incinerator. The HCW generation rate varies widely between HCFs.

Anicetus, H. *et al.* (2020) had measure measured and compared the waste generation rate in two different district hospitals in Tanzania (located in rural and urban areas, that is, Ligula and Amana hospitals) [13]. High rate of medical waste generation has been observed, about 2250 kg/day in Amana hospital and 2500 kg/day in Ligula hospital. The waste generation rate per patient per day was also reported to be high about 1.8 (Amana) and 2.0 (Ligula) kg/patient·day. Hamoda, H. M. *et al.* (2005) estimated the quantities of different categories of HCW generated at two different hospital categories (National referral hospital and regional referral hospital) in four hospitals in Dar es Salaam City (namely, Muhimbili National Hospital, Mwananyamala Regional Referral Hospital, Temeke Regional Referral Hospital and Ilala Regional Referral Hospital) to evaluate the quantities of effect of hospital level and bed capacity [14].

Other researchers have reported similar results globally, such as in Kuwait where the range reported was 3.65 - 3.97 kg/patient/day [14]. The daily medical waste generation rate is not constant, and fluctuates randomly [15]. The waste generation rate in kg/bed/day or kg/patient/day is required for effective onsite waste treatment operation, planning, budgeting and reporting [16]. The waste must be segregated and collected. However in another study [observed that about 6% to 10% of waste generated is left uncollected, which may affect negatively the performance of onsite waste treatment operation [17].

1.2. Establishing and Adhering to HCW Segregation Protocols

Waste container colour coding and labelling is an important aspect of medical waste segregation and also injection safety, which depends strongly on the HWs' perceptions. Colour coding and labelling helps HWs to locate containers they need for a specific type of waste. Moreover, color coding allows the waste handlers to put more attention on containers intended to contain sharps waste and minimize accidents. As stated earlier, improper handling of HCW can bring occupational hazards. The infectious waste generated in the course of healthcare services carries a higher potential for infection and injury especially needle stick injuries [17].

For the HCF to practice onsite treatment, all HWs must practice good HCW segregation [18]. The key to the effective management of healthcare wastes is segregation of the waste at the point of generation. Regardless of what final strategy for treatment and disposal of wastes is selected (onsite or offsite), it is critical that waste streams are segregated and remain segregated until treatment. In Tanzania, HCW segregation practices among HWs are overlooked and scarcely addressed [13]. There is no scientific report showing perfect waste segregation in the HCFs. Several hospital-based cross-sectional studies have been conducted to assess HCW segregation practices reports of which show that there is a need for strong supportive supervision and supply of requirements like waste bins, bin liners, trolleys for waste transportation, adequate staffing and training [17] [19] [20] [21]. The HCFs have been recommended to follow good standard precautions, establishing and maintaining onsite waste treatment systems and good supply of segregation containers. These recommendations form the most important variables assessed during this study in Tanzanian HCFs.

1.3. Waste Segregation during Generation, Transport and Storage

HCW that is not safely treated can have harmful effects on human and environmental health. In some countries, a large quantity of infectious and sharps waste produced at healthcare facilities is released into the environment without safe treatment. In Tanzania, an estimate of 11.8 kg of infectious waste was produced per day on average, but only 1.5 kg was safely segregated and treated [19].

While it is critical to ensure hazardous healthcare waste is safely treated and disposed of, it is also important to exclude non-hazardous waste from waste streams that require costly treatment processes, such as sterilization or high-temperature incineration. The components of HCW according to the Tanzanian categorization include: highly infectious, infectious wastes and sharps waste, and non-infectious waste. Similarly, the Irish categorization for better segregation so as to reduce the amount of HCW sent for treatment include: contaminated waste (high risk), uncontaminated waste (low risk) and clean packaging waste (no risk) categories [22]. A 2014 evaluation of the contents of infectious waste streams in Irish HCFs identified 66% of the waste stream as contaminated, 19% as clean packaging material that was non-hazardous, and 15% as uncontaminated and potentially not of risk.

The cost of incorrect segregation of non-hazardous waste from the hazardous HCW stream was an estimated 700 Euro per tonne. Based on the amount of waste produced (1.9 kg and 0.2 kg per in-patient bed at hospitals and health centres, respectively) the government estimated hospitals could save up to 27,000 Euro per year and health centres could save up to 6000 Euro per year by ensuring non-hazardous waste is excluded from hazardous waste streams [23].

In addition to the financial implications of appropriately separating waste, there are other resource limitations to consider, including space and disposal site management. In South Africa, healthcare facilities produced approximately 45,000 tonnes of healthcare waste in 2013. Authorized disposal sites have been unable to manage the large quantities of incoming healthcare waste and illegal dumping has been reported [24]. Segregating non-hazardous waste and excluding it from the hazardous waste stream reduces the amount of waste to be treated and, in places where safe disposal sites are overextended, can help alleviate health risks associated with illegal dumping of medical waste. Best practice waste management will aim to avoid or recover and recycle as much material as possible, to reduce the need for waste treatment and disposal.

1.4. Preparedness for Proper Waste Treatment Using Onsite Facilities

1.4.1. Target or Recommended Onsite Incineration Temperatures

High temperature two-chamber incineration is considered a safe treatment method for HCW, as it minimizes the formation of toxic compounds. In accordance with the Basel Convention, it is recommended that waste treatment techniques that minimize the formation and release of chemicals or hazardous emissions should be prioritized. Incineration or burning is widely practised, but can cause serious environmental pollution, including the formation of highly toxic dioxin and furan compounds if not properly designed and operated [25].

The Stockholm Convention sets targets for avoiding the formation of dioxins and furans by either avoiding combustion-based technologies or ensuring that combustion is done at high temperature: a first chamber should reach at least 850˚C, while temperatures in a second chamber should reach at least 1100˚C to minimize the formation of toxic compounds [26] [27]. This is based on global treaties to protect human health and the environment from highly dangerous, long-lasting chemicals, by restricting and ultimately eliminating their production, use, trade, release and storage. Where low-temperature burning is practised, HCFs should avoid burning PVC plastics and other chlorinated wastes that can lead to the formation of dioxins and furans. Such high temperature can be reached in High-Tech incinerators which are diesel fired [21], but questionable for De-Montfort incinerators.

1.4.2. Optimizing the Functionality of Onsite Incinerators in HCFs

Waste incinerators are not always functional and do not always have fuel available to operate, as reported in an assessment conducted earlier [28]. However, functionality and fuel availability for incinerators was reported to be 84% and 82%, respectively. This was below the rating for Nepal reported to be 91% and 94% [20], and well above the lowest rating reported for Bangladesh (60% and 54%, respectively, for the year) [12] while Somalia had lowest rating of 60% and 66% [28].

Furthermore, in Malawi, over half of HCFs had an incinerator, but at the time of the survey, the incinerator was functional at 88% of these facilities and fuel was available at only 45% of the HCFs. In Somalia, 15% of HCFs had an incinerator, but 60% and 66% of those had a functional system and fuel available, respectively [28].

1.4.3. Comprehensive Waste Management Practices in HCFs

Much of the waste produced in Tanzanian hospitals is either not segregated or not treated [16]. In Yemen, for example, a 2017 assessment of 72 hospitals found that each generated on average roughly 8.2 kg of sharps waste per day, of which 5 kg was not safely segregated and only 1.3 kg was safely segregated and treated as shown in **Figure 2** [28].

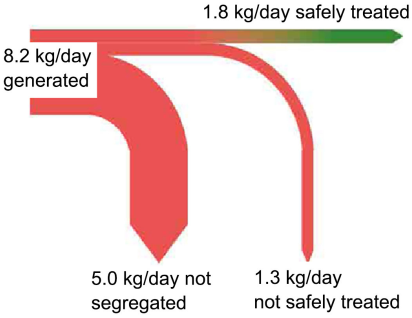


Figure 2. Generation, segregation and treatment of sharps waste in Yemen hospitals Source [28].

1.4.4. Onsite Healthcare Waste Prevention and Minimization

The Strategic Framework for the implementation of the Basel Convention for 2012-2021, adopted by decision BC-10/2 of COP-10 in 2011, recognized the waste management hierarchy as a guiding principle and included the objective "to pursue the prevention and minimization of hazardous waste and other waste generation at source, especially through supporting and promoting activities designed to reduce at the national level the generation and hazard potential of hazardous and other wastes". This applies well to the HCW generated in service delivery areas. Furthermore, COP-11 adopted by decision BC-11/1, the Framework for the environmentally sound management of hazardous wastes and other wastes which highlights the importance of prevention and minimization of hazardous wastes and other wastes.

Waste prevention and minimization has also been addressed in a broader context. It is addressed in Goal 12 of the 2030 Agenda for Sustainable Development, adopted by General Assembly resolution 70/1 in September 2015, to ensure sustainable consumption and production patterns. Here it states that by 2030, waste generation should be substantially reduced through prevention, reduction, recycling and reuse.

The benefits of waste prevention and minimization need no emphasis. Healthcare waste prevention and minimization contributes to the protection of human health and the environment, provides sustainable solutions, encourage good socio-economic and business practices by the HCF owners, and helps to better understand the environmental and health risks associated with HCW.

Waste prevention and minimization specifically contributes to, amongst other things, protection of human health and the environment. Sustainable and eco-friendly approaches to the prevention and minimization of HCW (especially hazardous components of the HCW) will reduce the environmental impacts of health service delivery as well as contribute to reductions in global warming, e.g., greenhouse gas emissions such as methane released from landfill sites and carbon dioxide from incineration. Another example is the substitution of chemicals categorized as Ozone Depleting Substances (such as CFCs and halons), in the materials flowing into the HCFs (**Figure 2**), which improves public health conditions.

Another benefit is efficient health service delivery practices. Waste prevention and minimization will improve resource efficiency through HCW management workforce efficiency, energy savings and material use reduction in HCFs. Waste minimization promotes efficient use of products and reduces the costs of purchasing new materials and energy consumption, leading to more output of product per unit of input of natural resources. When looked at a national level, this leads to higher economic return.

1.5. Special Onsite Waste Disposal Facilities

Placenta Disposal

Pathological waste management should include safe placenta disposal in any delivery setting. Generally, placenta sand pathological waste should not be treated with chemical disinfectants, which destroy the microorganisms that aid the decomposition process. A common treatment method in low-resource settings is a placenta pit, which allows the solids to biodegrade and liquids to percolate into the ground. While few countries have data on placenta disposal, Cambodia provides an interesting example from 2016. In 69% of hospitals and health centres, placenta waste was typically treated in onsite protected placenta pits in 20% the mother usually took the placenta home, in 6% the placenta was buried on the facility grounds, and the remaining 5% of facilities did not have delivery services. When healthcare workers were asked what the major WASH-related constraints were at the facility, 7% of respondents specifically mentioned the lack of a placenta pit.

1.6. Disposal of Incinerator Ash in Pits

Perceptions among Healthcare Workers (HWs) on Onsite HCW Management

Different views and perceptions observed in medical waste generation, segregation, collection, transportation and storage, treatment and disposal, between administrators and implementers affects HCW management, especially in the area of planning and resource allocation within HCFs [17]. In order to have a properly functioning onsite HCW treatment, the workers understanding and perceptions on all aspects of HCW management must be addressed [29] [30]. In this study, much effort has been put into identifying how HWs understand and cope with the problems of HCW management.

The analysis of HWs' perception on medical waste segregation included their practices on medical waste segregation by category of waste, where segregation is taking place in hospitals, type of containers used, and containers' colour coding and labelling [17] [31]. Thus, perception has a strong effect on success of onsite HCW management and incineration in particular.

The organization of collection and on-site transportation activities depends on the type of medical waste, human resources, infrastructure and equipment availability. At least two collections per day is a normal schedule in most HCFs (one in the morning and one in the afternoon), and whenever it would be necessary [32]. Medical waste collection, storage and transportation are three inter-dependent processes as per **Figure 1**, which connects the service areas to the waste collection bay and finally to the waste treatment. HCW collection is done inside hospital sections and departments. To make the process of collection possible and efficient, waste storage facilities need to be kept in place and sized correctly within the HCFs [13]. To remove medical waste collected at the generation point to the collection bay or storage bay, transportation facilities are important. Therefore, transportation infrastructure must match with the available workforce to minimize waste collection time. The popular containers used for HCW collection in Tanzanian hospitals are plastic bags, safety boxes and plastic bins [32] [33].

2. Methodology

A team of National and Regional level Assessors was formed to assess regional and respective district hospitals including lower healthcare facilities within the regions. The assessment of HCW management in the HCFs was conducted in all the 26 regions of Tanzania Mainland. From each region, at least four district/ municipal/town councils were physically reached by the assessors, and the remaining councils were reached by calls using mobile phones.

2.1. Research Instrument

Two research instruments were used, these are questionnaire, observational checklist and site visits.

2.1.1. The Questionnaire

A wide-ranging questionnaire was developed by the Ministry of Health in collaboration with higher learning institutions and WHO country office Tanzania, and was completed for all healthcare establishments in the selected regions in order to establish the following: number of hospital beds and bed occupancy rate for each healthcare establishment; types and quantities of waste generated, personnel involved in the management of HCW, current HCW disposal practices (including segregation, collection, transportation, storage, and disposal methods).

2.1.2. The Checklist and Site Visit

A standardized checklist and tools were used to assess and monitor various aspects related to HCW. These were in form of ODK, which is open-source software for collection, managing, and using data in resource-constrained environments. The software was opted due to its ability to easily handle data, and it allows for offline data collection with mobile devices in remote areas. It also provides a room for data submission to a saver when internet connectivity is available. There were three tools developed: a checklist for RHMT, a checklist for CHMT, and the survey tool for facility assessment. The survey tool was accompanied by direct observation, where several pictures were taken to complement the information collected through other tools.

2.2. Data Collection and Analysis

Since data sets were electronically prepared, they were coded with variable names, variable descriptions, variable format, etc. Thereafter, data were entered into a Statistical Package for Social Sciences (SPSS) computer software, or EXCEL sheet for further processing. This was followed by data cleaning process, which involved checking the data carefully for errors, accuracy, and identifying and handling missing values. Checking data for accuracy of the responses to questions included questions such as: are the responses legible? Are the responses complete? Are the important questions answered? Is all relevant contextual information (e.g., data, time, and place) included? Lastly, descriptive statistics such as frequencies, percentages, and means were performed and presented in tables and charts.

3. Results and Discussion

3.1. Healthcare Waste Generation Rate

To effectively operate an onsite waste treatment facility, one of the first critical steps in the process of developing a reliable waste management plan requires a clear understanding of the amount of waste generated on daily basis and the management system in place. This study aimed at assessing the HCW generation rate to enable identification of the necessary infrastructure for its management and onsite treatment in HCFs.

Results show that HCW generation rate strongly depend on bed capacity and on the daily number of patients attended in the Inpatient Department (IPD) and Outpatient Department (OPD), as summarized in **Table 1** below. Moreover, the kg/bed/ day was determined, and compared to the literature values.

Table 1. Waste generation rate for the HCFs of different levels.

Average capacities	Regional	District	Health Centre
Bed capacity	261.3	103.4	50.5
Daily IPD	103.7	43.7	28.7
Daily OPD on Weekdays	441.4	176.9	72.0
Waste generation (kg/day)	785.7	311.6	60.6
kg/bed/day	3.007	3.014	1.5

Results show that the kg/bed/day from this study was lower compared to the literature data, attributable to estimation only, while other did actual value measurements [17]. The data was equivalent to the study results when expressed as kg/inpatient/day, indicating that the bed occupancy was almost 100%.

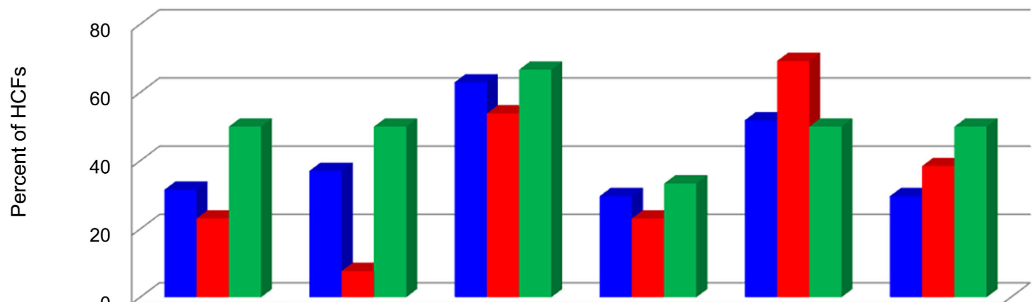
Previous study [17], indicated an average values of 2.0 and 1.8 kg/patient/day and 7.0 and 7.8 kg/bed/day for Ligula and Amana hospitals, respectively. Hence, for effective onsite waste treatment system, HCFs need to establish data on number of patients/day, number of beds and the corresponding occupancy rate in the facility and the total infectious waste generated per day that requires incineration. It is also recommended that the HCW categorizations should be based on WHO recommendations which presents 8 categories as reported earlier [17], that is, general, pathological, radioactive, chemical, infectious, sharps, pharmaceutical and pressurized containers. However, due to intended use of data such as implementation of autoclaving program, used a different categorization or waste identification style [13].

The effectiveness of the waste collection process is another factor that relates to the waste generation data. For efficient use of onsite incineration, the waste collection efficiency must reach 100%, that is, all wastes must be collected so that all infectious waste generated per day is sent to the incineration facility. Where the generation rate is higher than the incinerator capacity (for example in case of eruption or diseases or emergency cases like COVID-19), the number of incineration cycles can be increased from one to two per day to avoid piling of untreated waste at the storage bay.

Based on similar studies in other parts of the world, the median waste generation rate was found to be varied from 0.361 - 0.669 kg/patient/day comprising of 58.69% non-hazardous and 41.31% hazardous wastes in Ethiopia [15]. The fraction of infectious waste was reported to be the same among the hospitals studied, that is, 20.6% [17]. For effective operation of the onsite incineration facility, it is further recommended that HCFs struggle to minimise generation rate and safely dispose of HCW. Several actions are suggested: examining waste to understand quantities, sources and explore options for their proper management; improve waste segregation into reusable, recyclable, infectious, etc.; install high efficiency incinerator; discourage use of disposable items where options existed including drinking water bottles and utensils to minimize generation of non-infectious waste; and, reducing food waste considerably (by controlling portions sizes, better food management, and using waste for farm compost and animal feed).

3.2. Ongoing Activities Related to HCW Management Plan Implementation in the HCFs

By having HCW management plan in the HCF, its implementation covers a wide range of activities on annual basis. During this assessment, about six activities were observed in the different HCFs, as shown in **Figure 3**. The activities were mainly; training of HWs, combustion of incinerators, purchase of waste bins, construction of pits, purchase of safety boxes and preventive maintenance. The most common activity in healthcare centers was purchasing of safety boxes for improving injection safety (69.2%) and purchasing of waste bins (53.8%). In the district hospital, purchase of waste bins was the most frequent activity.



	Training of HCWs	Construction of incinerator	Purchase of waste bins	Construction of pits	Purchase of safety boxes	Preventive maintenance
District	31.5	37.0	63.0	29.6	51.9	29.6
Health Center	23.1	7.7	53.8	23.1	69.2	38.5
Regional	50.0	50.0	66.7	33.3	50.0	50.0

Figure 3. Ongoing activities in the HCFs related to HCW management observed during the study.

3.3. Proper Waste Segregation Practices

The key to minimization and effective management of HCW is segregation (separation) and identification of the waste (usually by using colour codes). Appropriate handling, treatment, and disposal of waste by type reduces operating costs and improves public health protection. Moreover, the health of staff and waste handling personnel (or waste handlers) is also improved. Segregation should always be the responsibility of the waste producer and should take place as close as possible to where the waste is generated. Waste segregation should be done immediately as the waste is generated. Segregation should also be maintained in storage areas and during transportation. The same system of segregation should be enforced throughout the country. The most appropriate way of identifying the categories of HCW is by sorting the waste into colour-coded plastic bags or containers.

The colour coding recommended for HCW collection bins according to national regulations and standards in Tanzania is shown in **Figure 4**. During waste segregation, the bins of different types, shape and sizes are normally arranged is a designated area of service delivery ready for collection when 3/4-full. **Figure 4** shows different types of containers, made of plastic, which are clearly identifiable by standard colours (red, yellow and blue or black, for highly infectious waste, infectious and sharps waste, and non-infections or general waste, respectively).

	Highly infectious	Anatomical waste, blood, body fluids, pathological waste, culture materials, stocks, petri dishes, waste from isolation ward or camp.
	Infectious wastes and sharps waste	Used gloves, dressing materials, specimen containers, infusion packages, catheters, urinal bags, used syringes and needles, surgical blades, scalpels, needles, scalpels, prickers, blades, broken glass (e.g., pipettes, ampoules, vials)
	Non-infectious	Paper, packaging materials, plastic bottles, food remains, boxes, cartons

Figure 4. Colour coding for HCW collection bins according to national regulations and standards.

Containers should be puncture-proof (usually made of metal or high-density plastic) and fitted with covers, safety boxes for collection of syringes and needles are however, made of cardboard. They should be rigid and impermeable so that they safely retain not only the sharps but also any residual liquids from syringes. To discourage abuse, containers should be tamper-proof (difficult to open or break) and needles and syringes should be rendered unusable prior to throwing into bins or sharps boxes. Where plastic or metal containers are unavailable or too costly, containers made of dense cardboard are recommended for ease of transport and may be supplied with a plastic lining [28].

Figure 5 shows bins with colour coded liners, bins with covers, bins without covers, and liners 3/4-full ready for collection. During the survey, most of the bin liners were observed to carry no labels, which are strongly recommended.

Figure 5. Bin liners and waste collection bins (labelled and unlabelled bin liners) with recommended colours (red, yellow and black/blue).

Bags and containers for infectious waste should be marked with the international infectious substance symbol, wherever possible. Most of HCFs assessed do not adhere to this requirement. Appropriate containers or bag holders should be placed in all locations where particular categories of waste may be generated. It was observed that most of the bags and containers were placed down the floor near the container. Instructions on waste separation and identification should be posted at each waste collection point to remind staff of the procedures. Results of this survey reveals scenarios of lack of bin liners in the HCFs, lack of colour coded bins, lack of labelling of bins, and lack of colour coded bin liners.

Staff should never attempt to correct errors of segregation by removing items from a bag or container after disposal or by placing one bag inside another bag of a different colour. If general and hazardous wastes are accidentally mixed, the mixture should be treated as hazardous healthcare waste and managed accordingly. Moreover, the waste should remain segregated until loading into incineration chamber.

3.4. Categories of Staff Designated for Waste Collection in HCFs

Healthcare workers in facilities are all in one way or another involved in the process of healthcare waste management particularly at generation and segregation. Even this requires orientation and understanding of principles of waste management Waste Management includes activities that are related with the generation, collection, separation, transportation, treatment and disposal of healthcare waste in a manner that is in accordance with the best principles of public health and other environmental consideration. Usually healthcare waste management includes administrative, financial, planning, engineering and environmental consideration in search of solution. There are mixed results in relation to collection and handling of healthcare waste generated in the assessed facilities, as **Figure 6** shows.

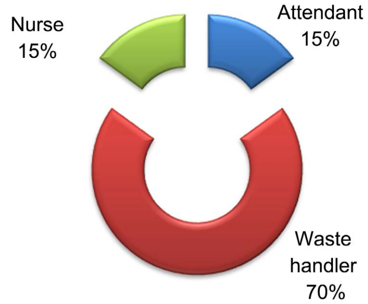


Figure 6. Handlers of healthcare waste in the HCFs.

The findings reveal that waste handlers were the most used personnel in collecting and handling healthcare waste from health facilities. Medical attendants and nurses equally participated in handling healthcare wasted in the surveyed facilities.

As shown in **Figure 7** waste handlers are used in regional and district levels extent than medical attendants and nurses. Medical attendants are used to a less extent (10.7%) in regional HCFs compared to district (22.9%) and health centers (19.4) due to work load demand for service delivery in the regional level HCFs. Nurses are used for HCW handling in lower level HCFs, such as district (11.5%) and health centers (9.7%) only, due to lack of staffing in these levels. The use of nurses as waste handlers in lower levels is misuse of hospital cardres. Where there were no designated waste handlers, other waste collection personnel observed include: casual labourers hired by the HCFs, company contracted by the HCF, employed cleaners, Red Cross teams, sanitation company staff and other HCF staff like laboratory attendants.

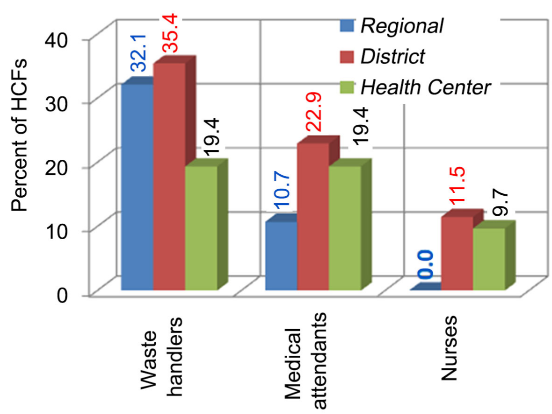


Figure 7. Variation of the percent of HCFs based on designation of staff for waste collection and transportation within the premises.

3.5. Incinerator Coverage in HCFs

Until new, appropriate, non-incineration technologies that respond to infrastructure and cost limitations are identified, incineration is a valuable, medium-term solution for safely treating and disposing of infectious waste including sharps in many resource-limited settings. Incineration uses combustion to make infectious medical waste harmless and reduce the waste mass and volume by more than 90%. Proper incineration can convert certain wastes into gases and incombustible solid residues (e.g., ash) that are relatively harmless. However as shown in **Figure 8** still of the overall healthcare facilities surveyed few 14.6% have standard incinerators and the rest are just burning structures or old not properly functioning incinerator.

Small-scale incinerators that meet minimum performance parameters can significantly improve current waste treatment practices, particularly in the short and medium term. Although WHO has not issued performance, quality, and safety (PQS) standards for small-scale incinerators, small-scale brick incinerators, such as the De Montfort and Waste Disposal Unit (WDUs), have been purchased and constructed for immunization campaigns and in some curative health settings. Experiences with small-scale incinerators in developing countries over the past ten years point to several performance criteria that reduce emissions and improve incinerator quality and safety. Although the WHO policy paper on safe HCW management does not identify clear performance criteria for small-scale incinerators, evaluations have determined that several factors improve performance. Ideally, small-scale incinerators should operate within a temperature range of 650˚C to 1000˚C, have at least two incinerator chambers, and have a minimum of one second of smoke-residence time.

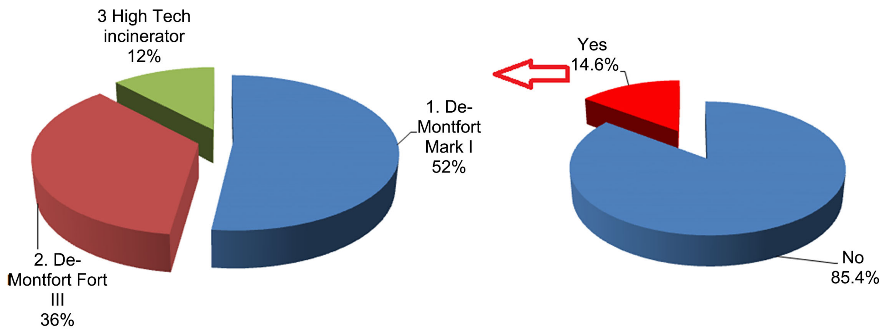


Figure 8. Types of incinerators in the HCFs which are operating onsite HCW incinerators.

3.6. Make of Incinerators Installed in HCFs

De Mont fort incinerators are dual-chamber types operated within the optimal temperature range of 650˚C to 1000˚C resulting in a lower level of emissions. The gases from De Montfort incineration are released into the atmosphere (with or without gas cleaning). Results show that less than 25% of the regional hospitals runs a De Montfort incinerator, while district hospitals and health centers operate either Mark II or Mark II De Montfort incinerators.

The survey shows that there is still a challenge in HCFs on selection of incinerator to suit their waste treatment needs. To be able to select a proper type and size of the incinerator, HCFs must determine their health system needs for HCW management treatment and disposal solutions. The type of incineration technology that best fits the facility needs can be determined by undertaking the following: mapping existing HCW management infrastructure. This includes finding out where the closest functioning incinerator or other treatment facility is located, and determining of transportation of HCW possible. If an incinerator does not exist, the best location to situate a centralized or onsite incinerator should be determined. It is also important to characterize the waste generated by the HCF by establishing the types of HCW produced and what types require treatment by incineration. The next step is to check land available on facility grounds for construct an incinerator (including an ash pit, placenta pit and storage bay). In order to properly select, construct and operate the incinerator, it is necessary to determine the average quantity of waste generated per day and to put in place an effective segregation system to minimize quantities of waste that require treatment.

3.7. Availability of Waste Storage Bays in HCFs

A storage location for health-care waste should be designated inside the health-care establishment or research facility. The waste, in bags or containers, should be stored in a separate area, room, or building of a size appropriate to the quantities of waste produced and the frequency of collection. Unless a refrigerated storage room is available, storage times for healthcare waste (the delay between production and treatment) should not exceed 48 hours in warm climate found in Tanzania. All waste bags or containers should be labelled with basic information on their content and on the waste producer. This information may be written directly on the bag or container or on pre-printed labels that are securely attached. **Figure 9** shows varied designs of transportation facilities available on market.

Figure 9. Waste collection trolleys with different design features.

The waste trolleys used for transportation of healthcare waste must be labelled for proper identification to avoid misuse. During this assessment, HCFs with labelled trolleys were identified, as summarized in **Figure 10**. Only 3.7% and 1.9% of health centers and regional hospitals, respectively, have labelled the trolleys, while still in the lower margin, only 11.1% of district hospitals were observed to have labelled their waste transportation trolleys. This indicated that this standard is not followed in the HCFs of all levels, which was also observed earlier [13].

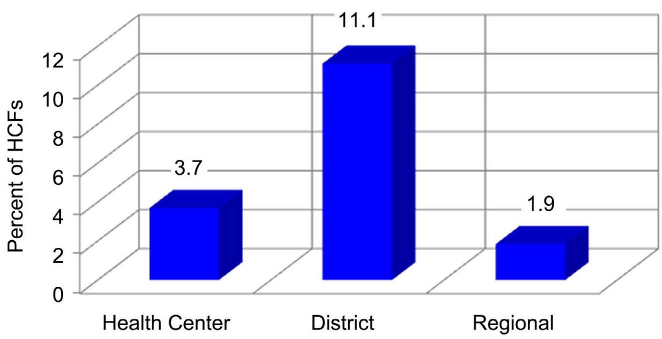


Figure 10. HCFs where waste transportation trolleys are designated and labelled.

It was further observed that where trolleys are not labelled, they are used for other purposes like: carry other stuff, carrying materials in construction activities, collecting boxes and equipment, for carrying drugs to stores, and for carrying wastes after cleaning activities [16].

Health-care waste should be transported within the hospital or other facility by means of wheeled trolleys, containers, or carts that are not used for any other purpose and meet the following specifications: easy to load and unload; and should have no sharp edges that could damage waste bags or containers during loading and unloading; easy to clean.

3.8. Ash Pit as an Incinerator Support Structure

Residue ash from proper incineration can be encapsulated in designated ash pits or controlled landfills without any major risk. However, when the conditions are not adequate, for example, when the waste is not properly segregated or the incinerator is not properly constructed or operated, toxic compounds can be found in the unburned waste, and harmful gases can be released into the atmosphere [19].

Figure 11 shows the fraction of the HCFs where ash pits have been constructed. While only 9.3% and 5.6% of the regional and district HCFs have constructed ash pits, only 20.4% of the district hospitals have constructed ash pits in the waste treatment areas. Another study reported 100% of the incinerators assessed in Addis Ababa to have no ash pits [33]. In many national jurisdictions and the international Basel Convention, this ash is defined as hazardous waste because of its hazardous chemical content and ability to cause harm. As a result, it should ideally be disposed of in a properly engineered hazardous waste landfill. However, wherever small-scale medical waste incineration is being carried out, there is unlikely to be access to any such landfill. In this event, an ash pit is essential to prevent uncontrolled disposal of the ash, which can allow the contaminants it contains to enter the environment or the food chain. Therefore, it is evident that incinerator ash is still a waste management challenge for HCFs in Tanzania.

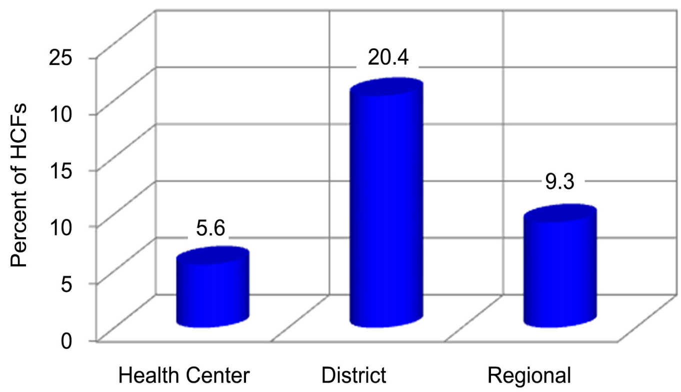


Figure 11. Fraction of the HCFs where ash pits have been constructed.

The hazards and safety concerns for as include heat, toxicity, environmental and food contamination and presence of sharps. The hot ash can cause burns and can also be blown by the wind, making it hazardous to handle when hot. Only handle ash when it has cooled. On the other hand, when ash contains dioxins and heavy metals, at varying concentrations depending on the type or category of waste incinerated and the conditions of incineration, it can be released in the environment. Environmental and food contamination by ash is easily spread by the wind rain water and many of the contaminants that it contains can be transported globally. These pollutants can also be taken up by domestic animals and passed on via eggs, meat and milk. If water gets into the ash pit, it can leach pollutants into the soil. Therefore, ash pits must be constructed using well-developed standards, normally provided by the Ministry of Health. Ash from waste incinerated may contain broken glass that cannot be destroyed, and also poorly combusted needles, lancets and scalpels that can cause injury.

As an example, a 100-bed district hospital in Africa might produce 180 kg of waste each day with a density of 225 kg/m^3. Assuming 95% volume reduction, *i.e.*, only 5% of the volume remains after incineration [34], the calculation would be: 72.9 m^{3}of ash to be produced over 5 years. The pit dimensions will then be 4.5 × 4 m × 4 m.

3.9. Fence, Accessibility and Leeway Side of the Incinerator Location

Incinerators should be installed in a protective enclosure or suitably ventilated building to prevent access by unauthorized persons and to protect the incineration equipment (burners, blowers, switches and electrical connections). A protective enclosure or building should ensure that the incinerator and other materials stored inside are protected from rain and UV radiation from direct sunlight. The incinerator is well ventilated and the stack emissions are clear of the building or enclosure so that the operator is not exposed to fumes when the incinerator is in use. The enclosure is robust and corrosion resistant, and its design-life is at least equivalent to the expected life of the incinerator [35].

Figure 12 shows the fractions of HCFs that have fenced their incinerators, have built the incinerators on the leeway sides of the facilities and those whose incinerators are accessible. About 58.3%, 31.3% and 30.8% of incinerators in regional, district and health centers, respectively, are located in areas which are difficult to reach due to poor access-roads, susceptible to weather conditions. Moreover, only 58.3%, 31.5% and 23.1% of the HCFs have fenced their incinerators, to discourage access by unauthorized people and pets [36].

The enclosure or building can be securely locked against unauthorized entry. There must be space within the enclosure to store the operator's protective clothing, tools, and equipment required to operate the system. There should also be sufficient space to conveniently store waste to be destroyed, as well as load and operate the incinerator safely without obstruction. The fence must have provision for an emergency exit should there be a fire or other emergency at the

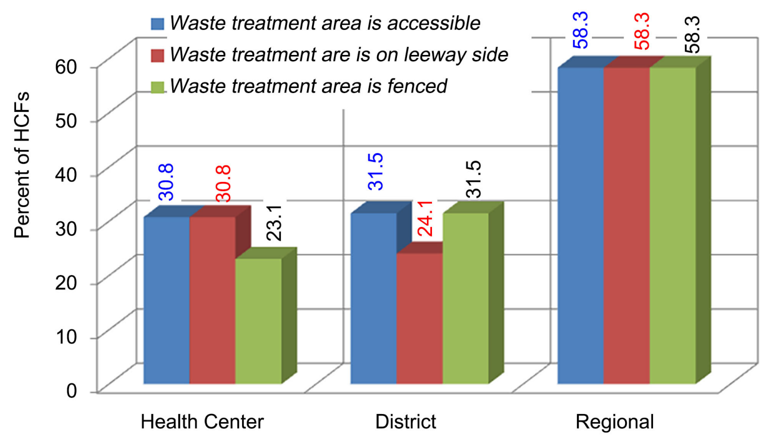


Figure 12. Fencing and accessibility assessment of onsite incinerators in the HCFs.

facility. There is a need for storage space for solid fuels or a storage reservoir for fuel in the incinerator house. This should be best located within the incinerator enclosure to ensure adequate security.

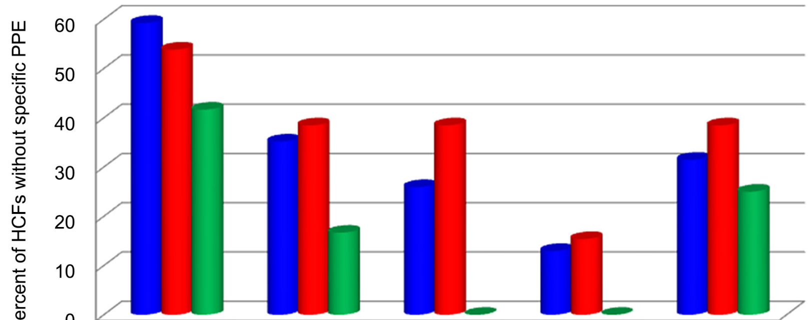
3.9.1. Lacking PPE for Operators in the HCFs

Availability and use of PPE reduces risk from sharps, germs, exposure to blood and other bodily fluids, and splashes from chemicals, inhalation of exhaust, and sparks from the incinerator.

Recent findings have identified gaps in the management of clinical waste in developing countries especially those of Sub Saharan Africa [20] [37]. However, these studies have failed to address the occupational health risks faced by waste pickers involved in the waste management process. Collecting, sorting, transporting and disposal of clinical waste is gainful employment and a source of livelihood to those involved, especially in developing countries. Possibly due to the informality of this activity, it goes by different names around the world. House keepers, waste collectors, cleaners and janitors are some of the names used to describe people involved in these kinds of activities. They are responsible for collection, transportation and emptying of clinical waste receptacles, to operation (and sometimes maintenance) of clinical waste incinerators and cleaning of hospital wards. The working conditions of these waste pickers with associated health hazards are summarily discussed with the aim of stimulating a global discussion and initiating debate worldwide among stakeholders and decision makers in occupational health.

HCW handlers in Tanzania certainly work under poor conditions which endanger their health given very low availability of masks and gloves, as shown in Figure 13. There is an urgent need for the implementation of health and safety protocols together with an overhaul of the equipment currently in use.

This paper further contributes to the growing body of scientific evidence which suggests that occupational health in developing countries is not sufficiently prioritized for some cadres in the health sector. Such insufficiency can intensify



	PPE-CAP	PPE-GOGGLES	PPE-MASK	PPE-GLOVES	PPE-APRON
District	59.3	35.2	25.9	13.0	31.5
Health Center	53.8	38.5	38.5	15.4	38.5
Regional	41.7	16.7	0.0	0.0	25.0

Figure 13. Distribution of HCFs with lacking specified PPE for waste handlers.

existing health hazards or can lead to the introduction of new ones. To curb any further negative health outcomes, there is an urgent need for sufficient understanding of the relation between occupation and health, surveillance and collection of data. In Tanzania, other obstacles could be the division of responsibilities between two or more ministries in the HCFs (those under LGAs and regional hospitals under MoH) and bottlenecks in the data collection process due to the fear of stigmatization.

The limited financial resources can be seen as one of the reasons for the poor working conditions of the waste handlers. The HCFs in which they work invest less on the safety and wellbeing of the waste handlers, partly because priority is given to the modernization of the facility and partly because the waste handers are often unskilled and are of low social status.

Given the absence of protective equipment in most facilities, the occupational risks faced by the clinical waste pickers can be curbed by improving hygiene, work organization, ergonomics and the purchase of better work tools such as mop trolleys for those who double as cleaners and gas masks for those who double as incinerator operators. In addition, focus on reducing risks of exposure to substances used for cleaning is essential. This can be achieved through the purchase of stronger utility gloves, water resistant working boots and goggles. Educating the waste handlers on the risks of their job and how these risks can be avoided is essential. The specific problem of chemical exposure can be addressed through focused information campaigns on their risks and health effects with particular emphasis on the most commonly used harmful solvents, supply and use of masks, gloves, aprons, caps and goggles.

3.9.2. Designation of Waste Treatment Supervisor/Coordinator

For effective onsite treatment of HCW, the hospital management is required to appoint a supervisor or coordinator. The appointed person must be given terms of reference, responsibilities and necessary support by the management. Some of the duties required include: regular supervision of incinerator and its support infrastructure, monitoring the process of healthcare waste disposal throughout the hospital, ensuring that trained technician and cleaners are using PPE during process of waste management. Other roles include: strong contribution in establishing and functioning of the HCW management/disposal committee, conducting training for hospital's staff regarding the proper management of HCW, and ensuring HCW storage area is well-managed and restricted from access by the public and animals/pets. The supervisor is expected to impose guidance on reducing the amount of waste generation through proper segregation. From time to time, the supervisor or coordinator is supposed to provide activity reports to the hospital manager.

During this study, HCFs were assessed for having appointed the HCW management supervisors or coordinators. It was revealed that 46.2%, 33.3% and 25% of the health centers, district hospitals and regional hospitals did not have appointed supervisors, as shown in **Figure 14**.

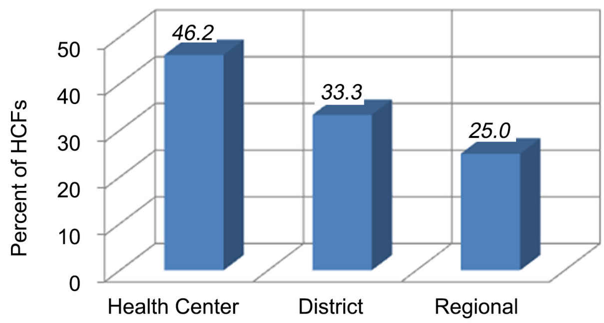


Figure 14. HCFS without designated HCW management coordinator.

It is important that incinerator operators are considered as critical towards safe healthcare waste disposal as the incinerator technology itself. A training program must be provided that develops a sense of pride in the role that incinerator operator plays in keeping healthcare workers and the community safe. The incinerator operator can impact the emissions generated by an incinerator by ensuring a primary chamber preheating temperature and controlling the rate of waste loaded. There must be a clear understanding of the guidelines for incinerator operation and it is important that incinerator operators have an opportunity to practice the proper operation of the incinerator with an experienced trainer and that follow-up training is planned. The trainers must also be able to communicate complex tasks in simple terms and be able to train at the incinerator site, working with the participants in an interactive training environment.

4. Conclusions and Recommendation

4.1. Conclusion

The level of preparedness in HCFs to implement HCWM protocols and incineration guidelines is fairly promising; currently standing at 50%. To effectively improve HCW management, the HCFs require a comprehensive HCWM plan. To address healthcare waste management issues within the HCFs, increasing budget allocation, preparing maintenance plans for the HCW equipment and machines, designating a HCWM Supervisor, redefining the term waste hander to become a recognizable professional tittle in the Healthcare delivery system, and ensuring availability of essential HCWM equipment and treatment and disposal options are key recommended interventions that call urgent action.

4.2. Recommendations

1) HCFs should establish waste management committee, comprising of representatives from senior management, departments which generate waste, waste handlers, infection control unit, procurement and stores, catering, long-term or resident contractors and waste management service providers. This committee should meet monthly or quarterly to discuss the key performance indicators (e.g., volume of waste generated, hazardous versus general waste ratio, incidents, audit findings, etc.) and to plan awareness programs and other initiatives to improve compliance with legal and other requirements, maintenance of waste management infrastructure, emerging challenges, etc. For smaller facilities, this committee can be the infection control/safety or health (and environmental) committee.

2) In the facility, regardless of level (regional, district or Health center), HCW management supervisor must be designated, trained and given the terms of reference, responsibilities and necessary support from the facility management. In some areas, they are known as Waste management officers, and are responsible for ensuring that waste is managed according to legal and other requirements, checking that standards are maintained, that everyone is aware of these requirements, that relevant personnel are appropriately trained and equipped to safely deal with waste in their areas. Moreover, they are responsible for making sure that all necessary data is recorded and transmitted to the waste management committee, facility management and regulatory authorities.

3) The term "waste handler" is generally used to represent staff/personnel responsible for waste collection, on-site transportation and treatment facility operation. The term is used when the actual designation of the personnel is not known, different from medical attendants and assistant nurses. Waste handlers must ensure that waste in the intermediate storage areas is properly segregated, contained and labelled. Any problems noted must be immediately brought to the attention of the responsible person in that area as well as to the HCW management supervisor, where applicable.

4) At each district and healthcare facility, the guiding principles for managing HCW should include identifying sustainable resources for safe and practical medical waste collection, handling, and transport. The MoH has for a long time prepared HCW management plans that include: safe handling of sharps (use punc-

ture-proof safety boxes or needle removal for disposal of all needles and plastic syringes. Dispose of all medical sharps safely) and safe collection of medical waste (by applying waste segregation and handling procedures in all healthcare delivery areas). Waste handlers must use personal protection equipment (PPE) and maintain a routine collection and transport schedule. However, supply of the PPEs in the HCFs brings a challenge for all levels (regional, district and Healthcare centers).

5) The safest final disposal option for public HCFs is incineration, which is done onsite. A complete, self-contained waste management system needs to be put in place. This includes an incinerator; a secure waste storage facility; a fuel store; an area for glass and sharps deposit; a protected ash disposal pit; a lockable secure enclosure for the incinerator; a facility to store the tools, protective clothing, and operator records; and a washing area with waste water runoff. In addition, a placenta pit should be built, because auto-combustion incinerators are not suited to destroying placenta. The pit should be located at some distance (20 meters or more) from the incinerator enclosure. Facilities with High-Tech incinerators installed, which use diesel-fired burners, do not need placenta pits.

6) All HCW management disposal facilities should be equipped with a water supply mounted above a concrete pad with either a gutter for runoff and percolation into the ground or connection to a drainage channel. All recipients (e.g., plastic containers, bins, etc.) should be thoroughly rinsed before being returned for reuse in the service areas. To improve healthcare waste segregation practice, health authorities should focus on sufficient allocation of onsite waste receptacles. In addition, periodic training on standard precaution will improve compliance with segregation practice [38].

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Disclaimer

The contents of this article represent the views of the authors and do not necessarily reflect the views of the organizations with which the authors are affiliated.

Conflicts of Interest

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

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