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ORIGINAL ARTICLE

# Healthcare waste management in Botswana: storage, collection, treatment and disposal system

**Daniel Mmereki[1,2] · Andrew Baldwin[1,2] · Baizhan Li[1,2] · Meng Liu[1,2]**

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**Abstract** Healthcare waste management has become a major issue of concern for solid waste managers due the treatment of healthcare waste being generated and the potential environmental risks and public health risks to those who come in contact with it. Special attention must be paid when dealing with healthcare waste because of infectious and non-infectious waste as well as general waste it contains. If managed through inappropriate healthcare waste management systems, it can adversely affect the environment and public health. In Botswana, the Waste Management Act was introduced in 1998 not only for healthcare waste handling, but also to promote sustainable treatment and disposal; the document currently applies to the management of all the healthcare waste, including liquid and chemical waste. The paper presents an overview of the current healthcare waste management in Botswana. A mixed methods study incorporating an exploratory survey was used. A range of data gathering techniques including observations, informal dialogues, published and grey literature and semi-structured interviews of selected participants and operatives dealing with waste were used to identify key policies, composition, storage, treatment, disposal, challenges and best practices. Specifically, sorting and storage, collection, treatment and disposal systems and the recent regulation of healthcare waste were discussed. Current storage facilities and collection services in the healthcare facilities (HCFs) were not operating effectively and efficiently. The composition was almost the same in the HCFs, with mean values in the following decreasing order: general waste (48.84) >medical waste (39.39 %) >sharps (13.13 %). Therefore, more attention should be paid on segregation of infectious and non-infectious from general waste, pollution prevention and recovery of valuable materials from HCFs. Several suggestions were made to deal with healthcare waste management problems efficiently and to prevent the potential impacts. These included development of a legislation to allow for a more defined roles and responsibilities for healthcare personnel responsible for the handling and disposal of the waste streams at the point of generation in the HCFs. Therefore, there is an urgent need to formulate a more sustainable healthcare waste management system.

**Keywords** Healthcare waste management · Infectious · General waste · Treatment · Disposal system · Recovery

## Introduction

Healthcare is an important aspect in every country [1]. Nevertheless, the diverse waste generated by the healthcare system may have significant impacts on the environment and public, if not properly stored, collected, transported, treated and disposed of [2]. Healthcare waste covers a wide spectrum of hazardous and non-hazardous waste [3, 4]. Today, around the globe, healthcare or clinical waste generation, treatment and disposal are becoming issues of concern to waste management professionals, environmentalists, international agencies and governments, particularly in developing and transition countries [5]. Healthcare waste contains infectious pathogens, toxic chemicals and heavy metals and may contain substances that are genotoxic or

✉ Daniel Mmereki
dani.mmereki2@hotmail.com; dani.mmereki2@gmail.com

[1] School of Urban Construction and Environment Engineering, Chongqing University, Chongqing 400045, China

[2] International Research Centre of Low Carbon and Green Building, Chongqing University, Chongqing 400045, China

radioactive [6–9]. Of particular concern is the risk of infections to those who handle the waste and the general public [10], particularly in the vicinity of the authorized or unauthorized disposal sites and landfills [11]. During the past decade, large amounts of diverse healthcare risk waste discarded by HCFs have been rapidly piling up in emerging economies [12]. A World Health Organization (WHO) report states that 75–90 % of hospital waste is non-risk or "general" waste, comparable to municipal solid waste (MSW). The remaining 10–25 % of hospital waste is regarded as infectious and hazardous and may pose a variety of health risks [1]. If both these types are mixed together then the entire quantity becomes contaminated and harmful [1]. Today, there is a greater recognition worldwide that HCW should be managed properly [13]. However, the management of HCW in developing and transition countries is exacerbated by several factors, including lack of technological and economical capacities, social problems, inadequate training of staff responsible for handling and processing healthcare waste. Also, the absence of facilities and/or action plan for HCFs' management to recycle and recover such non-risk or "general" wastes to reduce HCW disposal costs as well as treat liquid chemical waste generated from the HCFs; inadequate organizational structure required to manage HCW; inadequate procedures for HCW assessments; inadequate HCW management plans and description of the roles and responsibilities of individuals and institutions related to HCW management [4, 11, 12, 14–18]. Several studies in Africa pointed out that healthcare waste management is still in its infancy; characterized by the lack of awareness on the impacts of healthcare waste [19], the total absence of medical waste regulations and a high incidence of non-compliance in cases where they exist [20, 21].

In Botswana, the problem of waste from HCFs has been widely recognized by the concerned agencies [22]. Although there is general emphasis on modern healthcare waste practices to reduce the risks of hazardous wastes to humans or environment by treating them first before being disposed in landfills, a systemic implementation of government regulations is inadequate. So far the majority healthcare risk waste generated in Botswana is incinerated, while healthcare waste that is regarded as non-toxic is either dumped openly or landfilled [23]. Waste is not collected according to their types, but rather is mixed together [24]. In most HCFs, the incinerators used for the treatment of HCW still utilize old technologies and are potential sources of significant quantities of hazardous pollutants such as dioxins, furans and heavy metals like cadmium (Cd), mercury (Hg) and lead (Pb) [25].

Very few studies have focused on country-scaled HCRW management in Botswana, but many of these were ad hoc projects carried out for central and local authorities and have not been published. Furthermore, to the best of our knowledge, data on healthcare waste composition and management are limited and unreliable. There are no readily available official data about healthcare waste, and in some cases it is mixed with domestic wastes. In recent years, the composition of the HCW is becoming more diversified and complicated, thereby presenting an increasing threat to the ecological environment and need to implement environmentally friendly strategies. Thus, a probe into HCW in terms of its characteristics as well as methods of storage, collection, treatment and disposal and the protection of environmental ecosystems is critical. Therefore, to fill the gap, this paper systematically assesses HCRW management to identify methods and approaches to implement regulation on sorting, storage, collection, treatment and disposal of HCW. It also identifies future directions that could be helpful for decision makers to better manage HCW in developing and transition countries, particularly Botswana. Previous studies have focused primarily on HCW generation and the challenges of HCW management and legislative context using a qualitative approach. The aims of this paper were to determine the composition and characteristics, observe the processes for waste collection, treatment and disposal in Botswana and provide a systematic compositional data to structure and implement a sustainable health-care waste management system.

## Material and methods

### Study objectives

The objectives of the study presented in this paper were threefold, as follows:

- First, to critically analyze Botswana's existing national healthcare waste management policy and identify areas of improvement involved the use of relevant published literature, document, records and grey literature searches relating to HCW management in Botswana as well as data to enable development of sustainable HCW management strategies.
- Second, to obtain information on the existing procedures and practices for handling and treatment of wastes produced in HCFs in Botswana based on data collected from HCFs in different localities used as case study examples. This involved site visits and observations to derive information for procedures for handling and treatment of HCRW, and ways to alleviate HCWM problems. Also, interviews and informal dialogues were conducted with operatives handling HCW. Face-to-face interviews were conducted with key actors, and group

discussions were held with stuff of the HCFs. Observations were conducted in HCFs to gain familiarity with HCW management strategies and to obtain visual evidence of how HCW management was being implemented. The questions asked during the interviews were tailored to derive information on sorting and storage, collection, treatment and disposal, as well the process of the implementation of HCW management strategies in each HCF and measures to improve the current HCW management situation. The information obtained was used to update the data collected from relevant published literature, document, records and grey literature searches.

- Third, to undertake waste characterization in the selected HCFs. Determining the composition and types of wastes generated is particularly fundamental as it can be the basis for formulating appropriate waste strategies and resource management plans. Site visits, on-site inspections and walkthrough of HCFs were carried out in wards to obtain visual evidence of how HCW management was being implemented. We also gathered rich, triangulated data on the context of composition of HRCW.

The study sites were selected from both public and private HCF to be investigative of the current waste management practices in HCFs in Botswana.

## Study area

Botswana is one of the countries experiencing rapid development and increase in socio-economic activities involving consumption and changes in lifestyles and ultimately waste generation. The country is bounded by Namibia to the north and west, South Africa to the south and east, Zimbabwe to the east and Zambia to the west (Fig. 1). It covers a surface area of 582,000 km$^2$, with a population of 2,024,904 in 2011, of which the urban population increased from 41 to 53 % between 1990 and 2010.

Botswana's healthcare delivery system is characterized by multiple healthcare providers. These include both the public sector and private sector suppliers and include facilities supported by religious organizations [26]. In 2010, Botswana's health system consisted of 3 referral hospitals under the Ministry of Health (MOH), 7 district hospitals also under the MOH, 2 mission district hospitals (fully funded by government, e.g. seventh day adventist), 3 mine hospitals, 2 private hospitals, 17 primary hospitals under MOH control and an array of private general practitioners. There are also over 104 health clinics with beds, 173 health clinics without beds, 349 health posts and 856 mobile posts under the Ministry of Local Government with the rest managed by the private sector [22]. Public

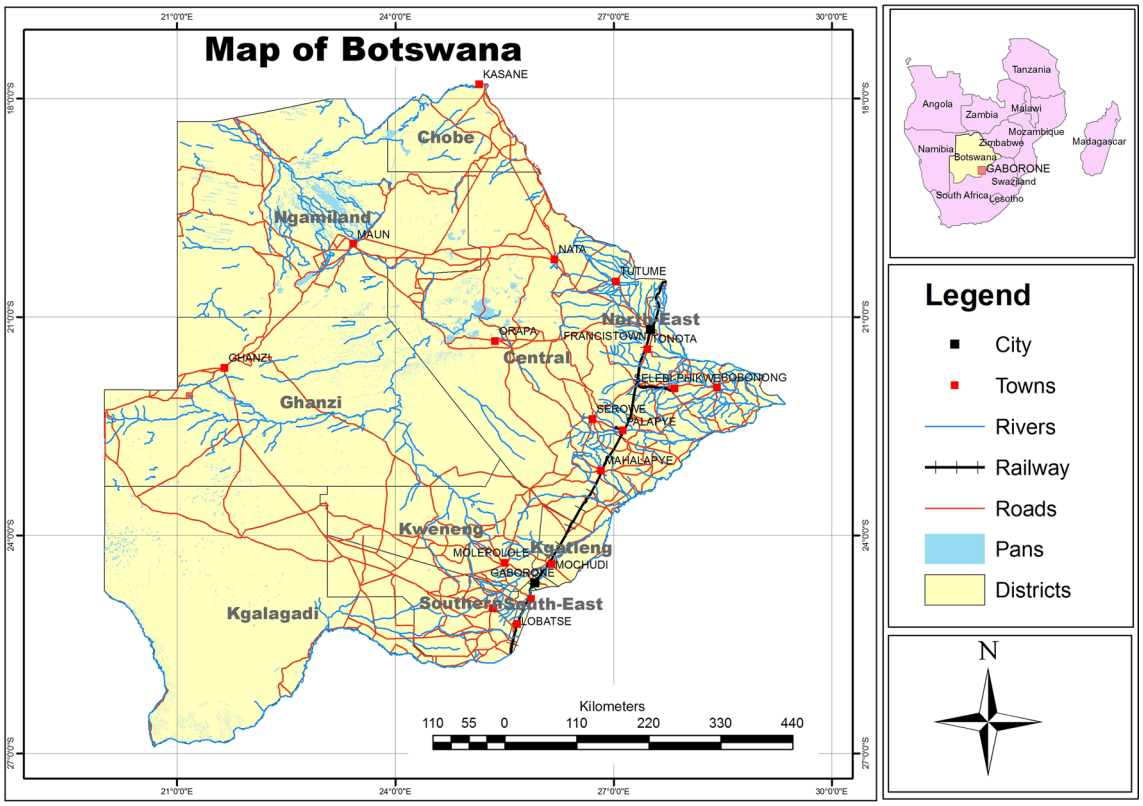


**Fig. 1** Map showing the location of the study area

and private sectors play complementary roles to improve the supply and provision of healthcare services to the population in terms of quality and access [23] and contribute towards public health improvement. Typically, there is a multitude of HCFs and establishments within the major villages, towns and cities [22]. However, current approaches adopted for handling and management of HCW in Botswana are not well documented, though this is the basis for formulating appropriate and sustainable waste and resource management strategies [23]. For example, appropriately identifying and determining the composition and type of individual fractions within the healthcare waste stream can enable regulators and stakeholders to make informed decisions about material reuse and resource efficiency.

In this study, public and private sector HCFs were purposively selected from urban areas such as Francistown, Gaborone, Selebi Phikwe, Lobatse and major villages such as Serowe, Molepolole, Palapye, Mochudi and Mahalapye for both qualitative and quantitative studies to determine the composition of HCW and HCW management practices, including storage and sorting, collection, treatment and disposal in Botswana.

### Survey methods

This study adopted mixed methods approach, but it was predominantly qualitative rather than quantitative. The semi-quantitative component involved determining composition and characteristics of HCW. Determining the composition of HCW is an important aspect. Also, compositional analysis is critical in selecting the best methods of collection, on-site storage, on-site processing, transport and final disposal as also making improvement of governance structures, designing and planning efficient healthcare waste management, including the development and delivery of long-term education and training policies for those involved at each stage in the disposal chain. A number of survey techniques were used to collect qualitative and quantitative data for the study. These are summarized as follows:

- Interviews were used to collect data on waste practices associated with storage, collection, treatment and disposal of healthcare waste from key HCF staff and stakeholders including general supervisors, sanitation workers and nurses who are directly responsible for handling of various waste streams at individual facilities. The questionnaires were designed to obtain information on sorting and storage, collection, treatment and disposal of HCW generated in HCFs. The results of the questionnaire surveys regarding sorting and storage and collection of healthcare waste by the HCFs were used to establish the operation of the healthcare waste management system.
- In each of the HCF investigated, site visits, including transient walkthrough inspections using an audit sheet were undertaken across the entire facility to identify the waste collection, handling and disposal practices at the facility. All health service delivery sections were included for the transient observation;
- Following the completion of the interviews and site walkovers, site visits to a few local HCFs, private facilities and treatment and disposal facilities were carried out to support and supplement information gathered by the surveys. Visual inspection and field investigations were similarly done to find out the management strategies and practices. This allowed the collection of first-hand information and experience of how solid waste is actually managed at the HCFs under normal working conditions. Healthcare waste treatment processes were examined during the facilities' visits.
- Review of related reports and previous research reports from the government sector and scientific articles was undertaken. The available literature was reviewed to allow comparisons to be made on storage, collection, treatment and disposal of healthcare waste in other countries. Data deficiencies in the study were tackled using experts' opinion. In this study, a group of decision makers and experts, including six environmental and system engineers who were experts in healthcare waste management were consulted. Due to the absence of healthcare waste generation data (sharps, infectious waste, general waste, etc.), we omitted this information in our study. However, it can be assumed that the quantity of waste generated is significant and may be increasing due to the wide acceptance of single-use disposable items.

Informed consent was obtained from those selected for interviews. Before data collection, the researchers described the goals and methods to those selected for interviews. Furthermore, the combination of qualitative and quantitative methods enabled to crosscheck the data gathered by different methods, thereby making the results of the study valid and credible.

## Results and discussion

### Regulatory response to healthcare waste in Botswana: the Botswana Clinical waste Management Practice

Botswana's policies dealing with any solid waste management, including healthcare waste focused predominantly on

the so-called "end of pipe" treatment [22]. In the year 1998, the government introduced a policy on pollution and waste management [23]. The main regulatory policy instruments related to the management of healthcare waste are as follows:

- The Waste Management Act of 1998 put more emphasis on the procedures for pollution prevention and waste minimization [27]. It is also so far the most comprehensive policy on solid waste management, including hospital waste. The policy tries to address the management of the entire waste handling process from generation to final disposal [26].
- The 1996 Clinical Waste Management Code of Practice: the Department of Waste Management and Pollution Control (DWMPC) developed a code of practice to provide guidelines for proper healthcare waste, including elaboration of a plan of action, and reduce risks exposure to infection and disease to medical staff. At the same, it provides procedures on cleaning and waste evacuation, employee training and education, and follow-up on waste management in the HCFs [28]. This code of practice is aimed at helping to handle healthcare waste as per the objectives of the Botswana Waste Management Strategy [29]. However, the lack of a legal definition for waste arising from HCFs and procedures for addressing the hazards and risks from the handling and processing of the waste stream results in inefficient and unsustainable management processes [30]. Additionally, the code of practices is not known by most of the health workers. Generally, the understanding of what really constitutes clinical waste by most healthcare workers in Botswana is lacking. The workers reported that they had never seen or used the Code of Practice [29]. The inadequate understanding or lack of knowledge of the Botswana Clinical Waste Management Code of Practice results in the application of different standards of practice by the different HCFs to manage HCW. Such discrepancies are evidence of a lack of an integrated approach and delivery of sustainable HCW management strategies [30]. Hence, there remains a need to put in place effective implementation strategies, including training and supervision of healthcare workers and those involved in the later disposal of discarded waste.

## Regulatory constraints

There were no enough follow-up and implementation guidelines put in place by the Government to persuade health workers to effectively implement the guidelines. The Code of Practice was developed to guide healthcare workers on managing hazardous waste generated in HCFs.

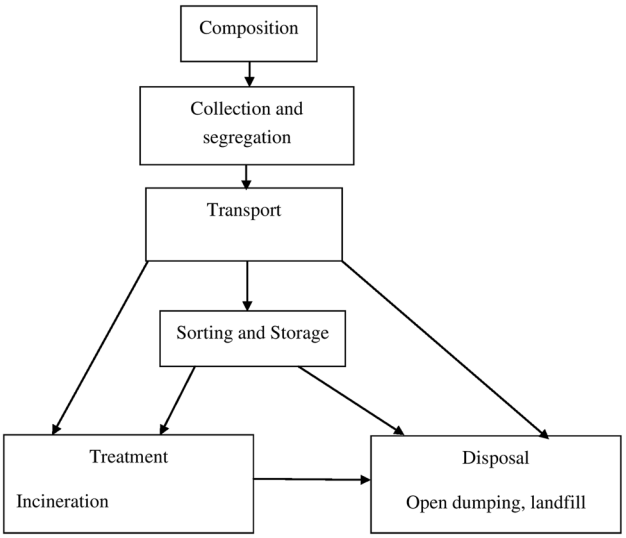


**Fig. 2** Summary of healthcare waste management practices at healthcare facilities in Botswana

However, the lack of publication or marketing of this document as an important tool for healthcare workers has contributed to this document not achieving its intentions to the fullest [29]. It is important, however, given the shortcomings that have been highlighted, that the Code of Practice is revisited or reformed, marketed and put to full use. This is an important step that could facilitate action in the different areas of concern such as health and safety, minimizing waste from the facilities and minimizing risks to communities and to the environment.

Figure 2 gives a summary of the management practices that were found at the HCFs in Botswana. Most of the management practices used were in line with recommended practices by the government. The major concern was that in most of the HCFs the guidelines put in place by the government were inappropriately implemented and were not fully followed [30]. Mixing of the different types of solid waste at the point of generation made it difficult for some practices in the flow chart to be efficiently implemented. Implementation of the code of practice on HCW management in HCFs in Botswana still had, therefore, a number of gaps that needed to be addressed. Most of these are discussed in detail below.

## Classifications, definitions and types of waste

None of the surveyed HCFs kept records on the quantities of waste generated. Waste characterization and compositional analysis was undertaken at the HCFs. Table 1 gives the classification of the waste generated at the HCFs, which is similar to other developing countries [31]. Waste is classified as general, medical or clinical and sharps. General waste is defined as HCW that does not pose any

**Table 1** Classification of the different types of healthcare solid waste at the HCFs

| Types of waste | Composition |
|---|---|
| General | Packaging materials (mostly cardboard), office paper, food remains, cans, plastic bags and containers, etc. |
| Healthcare (infectious) | Clinical specimen, culture plates, drainage bags, surgical waste, autopsy waste, blood, blood products and body fluids |
| Healthcare (pathological) | Human tissues, organs, foetuses, placentas, amputated body parts and other body parts |
| Healthcare (solid chemicals and pharmaceutical waste) | Spilled or expired drugs and chemicals |
| Sharps | Needles, syringes, broken glasses, scalpels, etc |

immediate danger to humans or the environment [32]. Examples of general waste include packaging materials such as cardboard, office paper, food remains, cans, etc. Pathological waste contains tissues, organs, placentas and other body parts [33]. Infectious waste is defined as waste that contains pathogens in sufficient quantity that when exposed can result in diseases [34]. Examples of this waste include culture plates, drainage bags, surgical and theatre wastes, contaminated plastic items, etc. Sharps are defined as anything that could cause a cut or puncture leading to wound [35]. Items like needles, syringes, scalpels, knives, broken glass, etc., form part of sharp wastes. All of these definitions are consistent with those reported in the literature [24–26]. However, neither of the HCFs had a clear definition of medical or clinical waste. Medical or clinical waste is only known to include infectious, pathological and chemical waste. From the literature, the terms hospital and medical wastes have often been used interchangeably [25, 26]. Lee et al. [25] used the term medical waste to deal with all types of wastes produced by HCFs rather than the term hospital waste. This is in direct opposition on how these terms are defined at the HCFs in Botswana. Hospital waste is, therefore, defined as any waste that is produced from HCFs such as general hospitals, medical centres, medical laboratories or animal hospitals. This, therefore, includes both non-hazardous and hazardous waste constituents. Hazardous waste included isolation wastes (i.e. waste from isolated waste), infectious waste, chemical wastes, pressurized containers, radioactive wastes, waste with high metal content, pharmaceutical waste, pathological wastes, mercury waste, cleaning chemicals, contaminated sharps, body parts, etc. Non-hazardous waste is defined as such waste that does not pose any risk to human health or environment. Examples of non-hazardous waste found in the HCFs in Botswana included packaging materials such as cardboard, office paper, leftover food, cans, plastic, textile, garbage, metal, glass, etc. This proportion on the composition of HCW generation is comparable to those observed by other studies in Saudi Arabia [35], Mauritius [36], Croatia [37] and Indonesia [3]. Medical waste was found to mean all hazardous wastes except sharps. The classifications of the waste by the HCFs were taken so as to compare with international practices. It was not easy to obtain the classifications from the national government, as there are no regulations on healthcare waste but only guidelines contained in the Code of Practice. Generally, general waste represented over 48 % of the waste generated at the facility (Fig. 3).

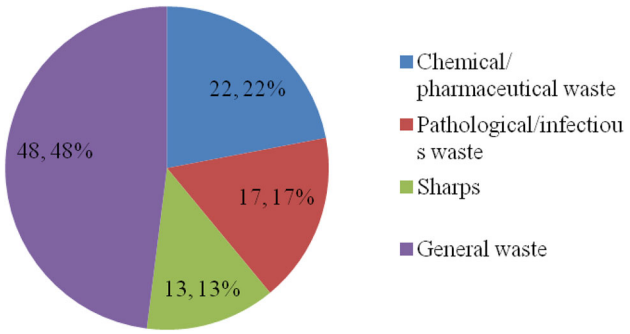


**Fig. 3** Relative proportions (annual) of individual waste types generated at a typical HCF in Botswana. The proportions are based on survey data from HCFs in Botswana

The types of waste generated in the HCFs are typical of any country [29]. What differ are perhaps the amounts generated due to variation in standard procedures executed in the medical field [25].

## Major compositions of the waste

Figure 3 gives the major composition of the types of waste generated in the surveyed HFCs. The composition was almost the same in the HCFs, with mean values in the following decreasing order: general waste (48.84) > medical waste (39.39 %) > sharps (13.13 %). The general waste category represented the highest proportion of waste generated in the majority of the HCFs. A majority of the HCFs offered inpatient services. This explains why general waste was high because of food-related services. This was not uncommon due to the fact that in many HCFs, the relatively large amounts of wastes generated come from the heavy reliance on disposable instruments and materials, the

increased packaging of products and the diversity of services offered [26]. The bulk of the general waste category was accounted for by cardboard and associated packaging generated from each department. Due to the fact that the general waste category (Table 1) represented relatively uncontaminated materials, they could represent a valuable resource for recovery and recycling from the waste stream provided appropriate systems are put in place.

The relative proportions of the individual waste streams as identified in the waste characterization study of the HCFs in Botswana are not different to those reported in the literature in other developing and transition countries with relatively higher proportions of general and uncontaminated wastes always being the highest fraction by volume and weight [10, 38, 39]. Overall, the results of the waste characterization and compositional analyses for a typical HCF in Botswana showed that there were potentially significant quantities of materials which could potentially be recovered from the healthcare waste stream as well as higher proportion of wastes such as sharps and chemical wastes, which are potentially hazardous and risky to public health and the environment.

## Healthcare waste collection and segregation systems

Solid wastes generated at all the HCFs were collected by contracted private companies at the start of each shift. The HCW was collected by operatives handling HCW and employees in each department using bins (normally placed at strategic locations in the facilities on corridors and close to work place), and packaged in coloured plastic bags (red plastic bags for hazardous waste, and black plastic bags for general waste to be disposed of with general domestic waste). The DWMPC has developed national guidelines on the management of healthcare waste [10]. Colour is used to differentiate containers for storing various types of healthcare waste at the generation point [29] (Table 2). Sharp instruments and needles are collected in closed plastic containers. Infectious waste should be stored in a yellow marked, strong leak proof bag or container. Chemical and pharmaceutical waste is supposed to be stored in a brown marked plastic bag or container. Black marked plastic bags in containers are to be used for storing general waste. Radioactive waste should be stored in a red lead box labelled with a radioactive symbol. Sharp instruments are to be stored in a yellow marked puncture proof container with covers on them [30]. However, the supply and availability was irregular and the HCFs' management complained of insufficient funds to purchase these containers, thereby limiting the effectiveness of the waste segregation and collection system. Compared to the public sector HCFs, the private sector HCFs appeared to have a relatively better waste collection system. Logistical issues often meant sharps bins were in short or irregular supply. Not all HCFs have optimized waste collection systems.

From the study findings, sharps, in particular used needles, were found to be the only types of waste collected using recommended containers in most of the HCFs because they were the most well-known type of hazardous waste. Hence, most of the HCFs disinfected sharps before their disposal. Typically, "sharps" were segregated in glass, plastic or cardboard boxes. However, the separation efficiencies were variable between facilities. Several of the "sharps" collection devices were observed to be broken and punctured. The poor packaging of segregated sharps and their inefficient recovery posed serious potential occupational and health hazards and risks during waste handling and disposal. This requires a specific study and is not discussed further in this study.

Hence, most of the healthcare workers were aware of the close association of used needles to the risk of HIV virus transmission through needle-stick injuries. However, during the survey period, it was observed that the intended waste segregation objectives of the colour coding system were not effectively implemented. As a result, the individual waste types and categories (Table 2) were routinely not segregated prior to final disposal. Infectious, pathological and chemical wastes were all collected in "red" plastic bags. This, to some extent, could be promoting mixing of these types of wastes during collection, as was observed in many wards. Practically, poor waste segregation practices defeat the principles of waste minimization, resulting with all types of waste being disposed of in red waste bags. One reason for using red plastic bags was that they were less costly and more accessible compared to other plastic bags recommended by the DWMPC. Similar

**Table 2** Showing the types of containers used to collect different types of hospital solid waste

| Types of waste | Container | Colour used by hospitals | Recommended colours |
|---|---|---|---|
| General | Plastic bag in bin container | Black/red plastic bag | Black plastic bag |
| Solid chemicals and pharmaceutical waste | Plastic bag in bin container | Red plastic bag | Brown plastic bags or container |
| Clinical and infectious | Plastic bag in bin container | Red plastic bag | Yellow plastic bags/container |
| Pathological | Plastic bag in bin container | Red plastic bag | Yellow plastic bags/container |
| Sharps | Bin beez | Yellow bin beez | Yellow bin beez |

findings were observed by Sabour et al. [40] who studied the mixing of infectious waste with non-hazardous medical waste in Jordan. In some wards, using on-site inspection it was also found that these wastes were also mixed with general waste. This type of mixing waste was common in most public HCFs. Only the intensive care unit and the gynaecology unit in the maternity ward were found to be efficient in separating the waste into the various types during collection. In a few instances, however, black and red bags were used interchangeably. This often happened when the red bags were out of stock. Even under such circumstances, the black waste bags would not be labelled properly to show that they contained hazardous waste, which was contrary to the Code of Practice.

The discrepancies (e.g. poor colour coding and mixing infectious waste with general uncontaminated wastes) associated with the waste segregation and collection identified in the HCFs investigated in Botswana have also been reported in waste characterization studies in other developing countries [40–42]. For example, Manga et al. [32] reported in Cameroon (case study of the Southwestern Region) that though it is required to segregate waste by toxicity using specific bags (i.e. yellow bags for infectious clinical waste and black bags for general uncontaminated waste), general waste streams are routinely mixed with infectious clinical waste. This practice has an effect of increasing the volumes of infectious waste as well as the treatment costs–a practice which diverts resources from areas such as training and sensitization, which could improve the implementation of sustainable waste management practices [35]. Compared to the public sector HCFs, private sector HCFs appeared to have a relatively better segregation system.

### Waste sorting and storage

Efficient sorting of healthcare waste by healthcare centre facilities helps to prevent and minimize the mixing of hazardous waste with general waste, which may lead to the waste stream being infected or contaminated [40]. Inadequate sorting of waste was noticed at the point of generation at all the HCFs. Sorting of waste was not commonly practiced in the majority of HCFs in Botswana, in particular, for infectious and hazardous waste as well as general waste, which was collected, transported and disposed in similar manner as municipal solid waste. However, a few healthcare facilities, particularly private healthcare facilities, sorted sharps, human tissues, radioactive and infectious waste from general waste partially segregated (placed in red containers, i.e. plastics), while pathological waste was stored in yellow containers. Sorting and storage, based on the different categories were not adequately done to allow efficient disposal. Critically, not all containers exhibit the universal biohazard sign that is commonly used in many countries. Most of the HCFs stored infectious sharps containers in general utility areas without any proper labelling or other precaution; this practice may also result in contaminated injection equipment being scavenged and reused. No external storage was found in any of the surveyed HCFs. General waste, instead of, however, being temporarily stored in the wards, was stored in designated stands outside each ward. The central storage rooms at some HCFs were found not to have any locking system, thereby allowing unauthorized entry anytime, which could be dangerous considering the types of waste stored. The rooms themselves were not in good condition, and plastic bags containing waste were put on the ground. Often, there were leakages on the floor from plastic bags containing medical waste, which could be a source of environmental hazard. Secured and sanitized storage systems should, therefore, be designed. In all the healthcare facilities, recycling of any segregated wastes is not currently being practiced on-site. What is more in most cases, packaging materials was not reused for HCWM. Tissues were stored in refrigerators, and all other wastes were placed in mixed containers at temporary storage before waste treatment. The temporary storage areas were well secured but poorly sanitized. Public HFCs do not have any temporary storage areas and the waste simply is dumped in the corner of the hospital yards until it was time for off-site transport. The infectious and non-infectious wastes were often not kept in separate containers and are often mixed together in the HCFs' own temporary storage area. Overall, most of the HCFs do not have any special place for the storage of HCW prior to disposal.

### Waste transportation systems

Health workers and nursing assistants were responsible for the transportation of wastes within the public HCFs. In all facilities surveyed, waste bins were emptied at least once a day, typically in the morning. Sharps containers were disposed of after every 2 or 3 days. Waste was, therefore, not allowed to accumulate within the wards to avoid decomposition, thus producing unwanted odours. This study identified poor waste handling practices by this group of workers, including the lack of use of personal protective clothing and equipment (PPE). Generally, this exposes the workers to high occupational and health hazards [31]. Wastes were manually transported (e.g. in metal bins and plastic bags) to the waste disposal/temporary storage sites with the use of trolleys or push trucks. This practice could lead to the leakage or spillage of waste content along the transport route, exposing workers, patients and the public to the risks of injury and health. Therefore, recommended procedures for cleaning of spills should be applied [39]:

spill kits should be available in each HCF, and HCRW should be collected and stored in labelled closed containers before proper disposal [30]. Wastes were transported to the central storage room and/or for appropriate management practices (Fig. 2). Poor waste management practices at the facility level, including failures in segregation and errors in colour-coding may result in hazardous waste not only being disposed of inappropriately, but also with members of the community, particularly scavengers gaining access to such waste.

Over and above with the lack of or inadequate training of operatives handling HCW, no effective occupational health programs were in place in Botswana including regular immunization, post exposure prophylactic treatment and medical surveillance. No special precautions for clearing spillages of potentially hazardous substances were available. Consequently, there was no continuous monitoring of workers' health and safety in the workplace to ensure proper transportation of waste. Managing waste is not considered a core business of HCFs in their efforts to control infections and accidents [30]. It is, therefore, not known how many health workers fell ill or met accidents that were related to waste management. These and many other handicaps not mentioned in this paper pose a challenge to the healthcare workforce and governments of developing countries, such as Botswana, that are not only faced with developmental problems but also many other healthcare delivery challenges [30]. Similar observations on HCW management were made in several major cities and urbanizing regions of Africa, Asia and Middle East [43]. Hence, HCW management should be tackled through capacity building, which involves staff training to improve the management of this sector, thereby leading to the improvement of the infrastructure.

## Treatment of healthcare waste

In Botswana, incineration, that is, on-site treatment has been the most common treatment method to handle healthcare waste that often contains infectious and hazardous materials, which accounts for the total majority (80 %) of the total waste stream. The remaining waste (less than 20 %) is treated by off-site incinerators at some general HCFs or landfill sites where incinerators are available. A majority of the healthcare facilities treated their own healthcare waste on-site by incineration, while other healthcare facilities use off-site incineration without employing steam sterilization with shredding of their HCRWs. Although incinerators were installed in some HCFs it was found that HCW was disposed of at MSW disposal sites, which may contaminate ground water, especially low-lying areas subject to frequent flooding. Other advanced treatment technologies such as high-temperature incineration, and the widely established "alternative" technologies, including autoclave treatment, were limited or limited in scope due to lack of the technical support and expertise. Although, this was not part of the main focus of this study, it was at the same time observed that there are presently no wastewater treatment plants (WWTPs) due to non-availability of financial, skilled human and infrastructural resources. Thus, liquid waste, wastewater and chemical waste were discharged into the general sewage system without the necessary precautions. To confirm this and to further assess the magnitude of the impacts, detailed investigations are required that consider various aspects related to them on the environment and public health. Recycling of medical waste, especially discarded PVC products, was not currently practiced in most of the HCFs in Botswana, with the exception of empty containers of antiseptics used for the collection and temporary storage of sharps. Therefore, the recycling and reuse of HCW is very important to reduction the waste generation as well as reduction the disposal cost.

## Incineration

In most of the localities, the total existing capacity of the incinerators was usually not much more than the required capacity to treat all of the generated waste per day. It should also, however, be noted, that the existing incinerators were not in suitable condition and not operating according to international best practices. For instance, materials containing chlorine such as polyvinyl chloride products (e.g. some blood bags, IV bags, IV tubes, etc.) or heavy metals such as mercury from broken thermometers were placed in red waste bags and incinerated contrary to the recommendation by the World Health Organization [44] that they should never be incinerated. This situation resulted in overloading of the few incinerators in the country [30].

The study revealed that in most of the HFCs, the incinerators used were rudimentary as they had poor design and operational problems. In the facilities assessed, incinerators were located within perimeter of the HCFs. It is worth noting that even the newest incinerators did not have emission control equipment. The primary hospitals in rural areas operated make-shift combustion furnaces. It is, therefore, desirable that proper waste segregation should be strictly adhered to and enhanced to reduce incinerator-related health risks downstream [29]. Commercial incineration plants for HRCW were rare. The incinerators installed in these healthcare facilities were not properly operated to destroy pathogens, resulting in "black smoke" and fly ash residuals, which are environmentally damaging and a hazard to public health. Due to inappropriate collection containers, maintenance support, acceptable energy sources and lack of understanding of operational instructions,

incineration of HCW was not safe. The incinerators in the HCFs were often old with minimal emission control systems for air pollutants. The incinerators were not fitted with typical air pollution control devices, including cyclones, semi-dry scrubbers and baghouse filters (or fabric dust removers). After incineration, the fly ash was disposed of in municipal waste landfill sites since Botswana does not have hazardous waste landfill, while the bottom ash was not tested to determine appropriate final disposal methods (i.e. hazardous or non-hazardous).

Properly designed incinerators should completely burn waste leaving a minimum of residuals in the form of ashes and should be equipped with scrubbers to trap the emitted toxic air pollutants [25]. In some facilities, the incinerators were self-made, were constructed from burnt bricks and cement and had a shape of house fireplace. Waste was burnt using coal as fuel, which did not allow proper control of temperature. Therefore, a high amount of ash was generated because of the incomplete combustion of waste. Moreover, the ash in the HCFs was openly dumped outside near the incinerators. None of the facilities had a specific procedure for the handling of ash and it was typically spread on land or disposed of in the open dumps. Incineration or open burning of healthcare waste releases pollutants which are usually emitted either in condensed (particulate matter) or gaseous phases [45, 46]. Their chimneys were also short and, depending on wind direction, emitted gases that were dispersed to nearby communities, causing nuisance and being a potential cause of bronchitis and pulmonary ailments such as asthma [10]. Waste that was improperly incinerated, especially containing plastic materials, is known to give rise to toxic gases such as dioxins and furans that are carcinogenic [25]. However, in Botswana there is currently no information on emissions of pollutants such as dioxins and PCBs with regard to healthcare waste incineration; the available incineration facilities were not equipped with emission monitoring devices [30]. With the current trend, where any waste ends up in the hospital incinerator, regular monitoring of the emissions from these facilities has to be instituted as a matter of urgency.

Most of the wastes incinerated at the HCFs consisted of human tissues, foetuses, placentas and body parts (Table 1). With proper incineration, these can easily be burned to ash without any problem [41]. Although at the moment plastics were not incinerated, the risk was high that they could find their way into the incinerators. Plastic materials as part of the waste encourage the release of dioxins when incinerated [46]. This is because plastics contain chlorine by-products such as polyvinyl chlorides (PVCs) [47].

The above-mentioned problems concerning the use of incinerators in healthcare solid waste management are consistent with ones reported by Mato and Kassenga [31] in a study of hospital waste management in Tanzania. The problems are typical of any developing country that cannot afford to buy more environmentally friendly incinerators with the latest technology [43].

A study by Palenik and Cumberlander [45] examined in detail the possibility of using autoclaves to treat contaminated sharps. Sharps are generally known to be capable of transmitting diseases. Thus, safe handling and disposal of sharps is an essential part of any infection control program [47]. The HCFs could also extend the treatment of infectious waste to sharps. Regular monitoring of the emissions from the incinerators would generate the necessary data, which could enable the Government of Botswana to accurately estimate the impact of healthcare waste on the environment. We, therefore, recommend that the Government of Botswana should invest on research to be able to have baseline information on emissions of dioxins and other persistent pollutants and come up with strategies to reduce human exposure.

## Disposal process of healthcare waste

The most common method of HCW disposal was open dump and landfilling. HCW was still mixed and dumped with non-clinical wastes in landfills without disinfection from micro-organisms. HCW was being deposited on or around open dumps. It was uncontrolled; hence, the waste was accessible to scavengers and animals. Also, wind could easily blow off the dumped waste, dispersing air pollutants to nearby communities. Although open dump was less expensive and no other alternative methods were available at reasonable cost, it was recognized as a potential infection source of public health and environmental pollution. Effective and efficient disposal of HCW was not considered a core business of health facilities in their efforts to control infections and accidents. The reason was that management had no direct involvement in the disposal system of HCW.

## Landfill

There are a few modern engineered landfills (i.e. Sanitary landfills) to minimize the risk assessment of the landfill hazards to preserve the environment and human health. Majority of the HCFs did not have landfills that were being used to dump all of the general and medical wastes, and this was the main problem of waste management practice at the HCFs. The landfills were located at a distance away from the HCFs. The main idea of the landfill is storage and containment of the waste deposited into it [23]. However, how the landfills are operated was in sharp contrast to normal procedures. At present, the landfills are operated like open dumps. Each day, the general and healthcare

wastes are dumped in the landfill and later burnt, which poses human health risk and environmental pollution concern. Burning was aimed at reducing the volume of waste and stopping the spread of papers. The burning itself is a potential source of generating toxic chemicals [47]. This was more likely since wastes such as plastics, syringes and paper were burnt together with HCRW. There is high chance that toxic chemicals like dioxins and furans are generated. Depending on the wind direction, when the waste was burnt, smoke may reach homes, dispersing toxic air pollutants. The community living near the landfill, therefore, would act as passive samplers through inhalation of polluted air [48]. However, the full extent of this threat has not been scientifically evaluated. Hence, it is high time to think about an effective sterilization technology to sanitize the HCW at the generation source before final disposal. The major disposal option of healthcare waste from most healthcare facilities was to pay licensed transporters to transfer waste to healthcare waste incineration facilities.

## Open dumping

Recommendations from the DWMPC state that incinerator residues should be disposed of in a landfill [26]. Nevertheless, the site survey established that all of the incineration residues from the HCFs were openly dumped at sites close to the incinerators comingled with municipal solid wastes. Open dumping has long been recognized as a potential source of public health and environmental problems [47]. The national government generally has accepted landfill as the final option of disposing hazardous hospital solid waste. Open dumping, because of its inherent problems such as leakage of toxic substances into the environment; easily accessed by insects, rodents and other small animals, most of which are disease vectors, has been replaced by landfilling in the management of solid wastes [30]. Also, wind could easily blow over the dumped waste, dispersing air pollutants to nearby communities.

The Waste Management Act 1998 stipulates that waste can only be disposed at a waste disposal facility that has permit issued by the DWMPC [26]. Such a facility must be properly designed, operated and monitored in accordance with permit conditions [35]. Despite this requirement, there was no evidence to suggest that the HCF management had permission to operate open dumps for bottom ash from incinerators. This was another example of a policy implementation gap between the government and HCFs in terms of how to handle health waste.

As part of the surveys undertaken in this study (Table 1), a number of disposal routes for the individual categories of waste generated were also investigated through staff interviews, informal dialogues and site visits. A summary of the health care waste disposal and treatment methods for each of the categories of waste in the facilities surveyed is shown in Fig. 3.

A summary of the waste disposal methods (Fig. 4), identified at each of the HCFs during the site visits at the HCFs at different localities, is presented in Table 3.

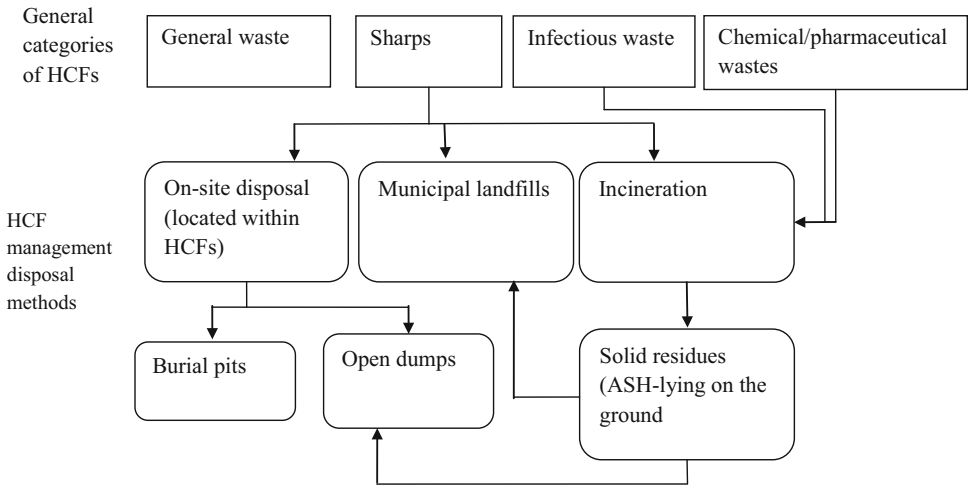


**Fig. 4** Patterns of health care waste management system in Botswana

**Table 3** Final waste disposal facilities in the hospital facilities surveyed

| Locality | Burial pits | Open dumps | Incineration | Municipal Bins |
|---|---|---|---|---|
| Villages | Yes | Yes | Not fully functional | Yes |
| Towns | No | Yes | Yes | No |
| Cities | No | No | Yes | Yes |
| Remote areas | Yes | Yes | N/A | Yes |

### On-site disposal in open dumps

Material segregation at the point of generation was carried out in some of the surveyed facilities, even though most of the waste categories collected individually were disposed of together in open dumps (Fig. 3), without consideration of the public health implications of the disposal methods adopted. For example, in some of the surveyed facilities (villages and remote areas), mixed wastes (Table 1) were disposed of in open spaces and in shallow on-site dumps which were periodically torched (during the dry season) as a form of treatment and pollution control. Although some of the HCFs were fenced, they still remained accessible to stray animals and members of the public. One of the major problems associated with open dumps whether on-site or off-site was access to unauthorized persons and environmental pollution; poor protection of municipal waste handlers and the practice of some informal material recovery (e.g. scavengers). Additionally, these dumps were unsightly, aesthetically unpleasing, health and safety hazards (e.g. inoculation injuries) and were breeding grounds for vectors such as the malaria parasite-carrying mosquitoes. The disposal of healthcare wastes in open dumps or landfills without adequate design considerations that guarantee the protection of the environment may pose serious health and environmental hazard [49]. Leachates from beneath the landfills or open dumps or surface runoffs may contain heavy metals and other organic pollutants that could lead to gross contamination of surface and groundwater resources [36, 37]. It has been reported in the literature (e.g. [9]) that the disposal of healthcare waste in open and uncontrolled dumps as well as landfills without special treatment is the most common unsafe waste disposal method in developing and transition countries [41]. The practice is very inefficient and poses serious risk to public health and the environment [9]. On the other hand, the lack of appropriate hazardous waste disposal facilities in developing and transition countries such as Botswana, largely due to limited financial and fiscal resources, leads to the persistence of hazardous practices such as the disposal of chemical residues into the sewerage systems and open dumps [30]. It is common practice for chemical waste in the form of pharmaceutical wastes (e.g. antibiotics and other drugs), heavy metals such as mercury, phenols and derivatives and other chemicals used in HCF laboratories to be disposed of into sewerage system.

It could be deduced from the surveys and observational analysis undertaken in the HCFs that the most common waste management options adopted for the management of health care wastes in Botswana are open dumping (uncontrolled landfills) and incineration. The selection of one method over another depends on the combustibility of the wastes. Easily combustible waste (i.e. paper waste, plastics, etc.) including sharps is destined for the incinerator while less combustible wet wastes are transported to open dumps.

### Trends of management of healthcare waste in developed countries

The developed countries generate higher amounts of healthcare waste than that of the developing countries [50–52]. North America produces 7–10 kg of healthcare waste per bed/day, whereas South America produces 3 kg of waste per bed/day. This difference was also found in Europe and Asia. Western Europe produces 3–6 kg, whereas Eastern Europe 1.4–2 kg of waste per bed/day. In Asia, richer countries produce 2.5 kg per bed/daily, and poorer countries 1.8–2 kg per bed/daily [1]. It is established that the amount of healthcare waste generation rate depends on the level of economic development of the region [37]. However, the developed nations are following advanced legislation, good practice guidelines defining medical wastes and guidelines during waste collection and appropriate technologies during waste handling, storage and transportation to minimize the clinical waste generation [5, 35, 52]. For instance, countries such as the US, Canada and Sweden have dedicated efforts to improve the management of healthcare waste and have led to a movement to regulate the waste more systematically and stringently [31]. In Western European countries, definitions of HCW exist, but differ from country to country. For instance, there is an established regulatory policy framework in relation to health care waste management [53], with drivers such as public health protection, and European Directives transposed into national legislation (e.g. the Hazardous Waste Regulations 2006 in the UK). Although significant progress has been made, yet it still requires further modification in all aspects of HCW management practices. In the European Union, high standards regarding HCWM have been adopted. For instance, in England a systematic approach is utilized in terms of waste minimization, organization performance, staff training and awareness [54]. Additionally, in the majority of developed countries, there are sufficient financial investment, awareness and effective control, infrastructure and equipment and trained clinical staffs in the waste management framework. In terms of risk associated with HCW, in developed countries, fortunately evidence has been scientifically substantiated on the actual content of micro-organisms, survival of micro-organisms in clinical waste and the infectious risks to healthcare workers and general public. Also, information reflecting the exposure, practices and risk situations of HCW is available [55].

Furthermore, the developed countries are replacing unnecessary incineration using potentially more environmentally friendly alternative treatment technologies for

medical waste, including microwave sanitation, chemical disinfection, dry heat disinfection, disinfection with superheated steam, pyrolysis and gasification. Noticeably, many developed countries have implemented stringent regulations to ban the incineration of HCRW due to emission of air pollutants, especially dioxins and furans. Hence, typical hospitals closer to cities are turning to alternative and higher technologies due to higher maintenance costs and serious environmental impacts [37]. In Europe HCW landfilling of HCW is strictly controlled because of the infectious nature of the waste and pubic abhorrence [48, 53]. It is evident that developed countries are driving efforts to reduce the use of PVC materials in medical products in the healthcare industry [55]. Data revealed that some countries have banned mercury-containing instruments. In developed countries like the US and UK, many hospitals are operating recycling programs to recycle uncontaminated solid waste materials like office paper, cardboard, metal cans and selected glass [25, 52]. For instance, many hospitals in the US are operating programs to recycle uncontaminated office paper, cardboard, metal cans and selected glass [25]. For recycling plastics at a hospital, Lee et al. [25] propose a methodology on how best to do it in each department/unit. One important thing is first to decide whether patients with potential infections used the plastics or not. All plastics not used by patients could be recycled along with those used by non-infectious patients. Those plastics deemed contaminated with infections should be disposed of in a landfill [40].

Developing countries are trying to develop new efforts for more comprehensive schemes regarding eco-friendly medical waste management [44], Botswana being one among them. These countries have learned much from the experiences of the forerunners on HCW management such as the US, Sweden and Canada [25]. However, countries should not directly implement the approaches used by others; they must learn from forerunners and develop a proper HCW management plan according to the country's perspective. The management plan implemented should take into account the political, fiscal, scientific, technical, social and economic aspects. The fiscal, economic, social and political barriers characteristic of developing city problems will need to be recognized and analysed [39].

## Suggestions and conclusion

The proper management of healthcare waste has become a major concern for solid waste professionals, managers, environmentalists, etc., because of the diversity in the composition of the waste stream and a presence of myriad of infectious and non-infectious materials as well as general waste within it. A variety of healthcare waste has been increasing due to the wide use and emergence of pandemics. While there are established mechanisms for handling and processing this waste stream in developed countries, it is often not recognized as a specific problematic waste stream in developing countries such as Botswana. Therefore, the main problem of healthcare solid waste management in Botswana area was due to improper solid waste storage, packing and transportation as well as lack of facilities. The most common treatment and disposal methods adopted for HCW management in developing countries such as Botswana are open dumps or uncontrolled landfills and poorly designed landfills as well as incineration without adequate measures to deal with toxic emissions to air, soil, water and potential health hazards to humans. Additionally, majority of the HCFs practiced open-dumping and followed inappropriate storage, sorting, collection and transportation procedures, which were not environmentally friendly. The infectious waste is often mixed with general waste and treated in incineration facilities or disposed of in municipal solid waste landfills. It was observed that healthcare waste management was left to junior support staff in these facilities. The lack of Healthcare Waste Management Plans or an assigned staff member (Environmental Practitioner) to manage or coordinate waste management activities at facility level was our basis for this conclusion. No induction training on healthcare waste management was conducted for new workers. Only a few facilities trained their workers on the management of such waste. No hazardous waste landfills are available in Botswana.

A number of regulation and guidelines have been developed to better manage healthcare from HCFs but their operations and inappropriate technologies leave much to be desired. An integrated system to manage this waste stream has not been established. Botswana's Department of Waste Management and Pollution has not initiated measures for recycling healthcare waste from HCFs. Therefore, several suggestions can be made to improve the current HCW management practices in Botswana. Although the cost of options was cited as the main reason for poor waste management, the waste managers at the HCFs could still do much with the limited resources to improve the situation. The need for Healthcare Waste Management Plans at facility level cannot be overemphasized. This would enable facilities to plan for all the necessary resources, including staff training, monitoring and evaluation of waste generated from the facilities and finally enable facilities to take charge of all their activities that are likely to generate waste.

First, public mindset change on the need for HCW recycling, in particular of general waste, should be greatly promoted. A major challenge for healthcare waste was related to a lack of change of mindset and public

awareness of the potential for recycling general waste from HCFs. Change of mindset and public awareness of potential for recycling general waste should be a priority for municipalities; it is essential that municipalities and HCFs create public awareness about the importance of recycling healthcare waste, particularly general waste, and potential impacts of infectious waste on public health and the environment, if improperly managed. Furthermore, one of the major challenges for healthcare waste recycling was the need to establish proper programs for a stable supply of general waste to be recycled. Especially, programs for healthcare waste recycling by local governments and HCFs. Local governments should provide a place (municipal transfer station) within the municipality where private transporters contracted by government could hand in general waste from healthcare to recovery companies. Waste minimization, through source reduction, reuse and recycling, also has to be effectively implemented to decrease the amount of healthcare waste disposed. Waste minimization can be achieved by the following strategies: (1) encouraging HCFs to recycle their waste and (2) establishing effective policy for promoting healthcare waste recycling in collaboration with the private sector.

Recycling options should become major part of HCW management in Botswana because incineration and landfilling are currently unsustainable. Reuse and recycling of healthcare waste conserves precious materials in the waste and reduces the environmental and public health impacts of these waste upon disposal. Finally, the most effective schemes which could directly reduce the solid waste disposal pollution include the following:

- Source reduction
- Implementing the research projects related to the recycling of HCW
- Solid waste treatment
- Disposal of domestic and semi-domestic solid wastes generated in the HCFs in municipal landfills.

Other schemes that could have an indirect impact on solid waste pollution control, as well as the schemes aimed at improving the effectiveness of the existing mechanisms consider the following general themes:

- Developing comprehensive management information systems (MIS) for HCW generation and management in Botswana.
- Capacity building and human resources development for solid waste recycling in HCFs. Training the staff on solid waste management systems in different HCFs.
- Developing local regulations and guidelines for HCW collection, separation, storage, transportation and disposal considering the existing national regulations.
- Monitoring and evaluation of the solid waste management systems in the HCFs.

Overall, significant improvements in the current practices for the handling and management of health care waste in Botswana are required to ensure public health and environmental protection as well for recovering significant quantities of recyclable materials and resources from landfills.

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**Compliance with ethical standards**

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