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AIDSFree Strengthening High Impact Interventions for an AIDS-free Generation

STRENGTHENING HIGH IMPACT INTERVENTIONS FOR AN AIDS-FREE GENERATION (AIDSFREE) PROJECT

HEALTH CARE WASTE CHARACTERISTICS AT SELECTED HEALTH FACILITIES IN MBARARA DISTRICT, UGANDA

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CONTENTS

LIST OF TABLES

ACRONYMS

DOTS	directly observed therapy, short course [for tuberculosis]
eMTCT	elimination of mother-to-child transmission [of HIV]
GLSL	Green Label Services Ltd
HC	health center
HCW	health care waste
MOH	Ministry of Health
OPD	outpatient department
PEP	post-exposure prophylaxis
PPE	personal protective equipment
RRH	regional referral hospital
SIMS	Site Improvement through Monitoring System [PEPFAR]
UNEP	United Nations Environment Programme
VMMC	voluntary medical male circumcision
WHO	World Health Organization

1.0 BACKGROUND

1.1 Definition, Sources, and Recommended Best Practices

Health care waste (HCW) is a byproduct of health care that includes sharps, non-sharps, blood, body parts, chemicals, pharmaceuticals, medical devices, and radioactive materials (World Health Organization [WHO] 2016). It is generated at hospitals, medical centers, polyclinics, dialysis centers, cancer institutes, maternity centers, immunization centers, service outreach posts, dental clinics, physicians' offices, blood banks, nursing homes, veterinary hospitals, home health care settings, emergency service facilities (e.g., ambulances), autopsy clinics, funeral homes, tattooing and cosmetic centers, first-aid posts, health and quarantine areas, isolation units, rehabilitation centers—and many other places.

The HCW produced in the course of health care activities has a higher potential to infect and injure than does any other type of waste. Inadequate and inappropriate HCW handling knowledge may have serious health consequences and a significant negative impact on the environment as well (Mathur et al. 2011).

According to WHO (2015), about 85 percent of the total amount of waste generated by health care activities is general, nonhazardous waste. The remaining 15 percent is considered hazardous material that may be infectious, toxic, or radioactive. Annually, an estimated 16 billion injections are administered worldwide, but not all needles and syringes are properly disposed of afterward, despite the fact that HCW contains potentially harmful microorganisms that can infect hospital patients, health workers, and the general public.

WHO continues to warn that the HCW discarded without treatment in open dumpsites has significant negative health impacts, especially in developing countries, due to scavenging, waste workers' lack of personal protective equipment (PPE), and the limited availability of immunization. Some incinerated HCW may emit dioxins, furans, and other air pollutants (WHO 2015).

Reasons that improper HCW management practice is alarming in developing countries include inadequate resources to manage waste and that waste management is often delegated to poorly educated and untrained laborers who perform without proper guidance or adequate protection (Soares et al. 2013 and Diaz et al. 2005).

In Pakistan, scavenger boys who sort medical waste to collect items for resale were reported to experience on average three-to-five needlestick injuries a day (Alfat and Mujeeb 2002). Where as in Tanzania, health care solid waste is still handled and disposed with domestic waste, creating a public health risk (Kuchibanda et al. 2015).

However, if the HCW is properly handled and disposed, health hazards are minimized. In addition, several scholars have suggested that planning and implementation of waste management can reduce health and environmental risks (Kuchibanda et al. 2015). Some of the WHO activities to handle HCW properly include developing technical guidance materials for assessing the quantities and types of waste produced in different facilities; developing national HCW guidelines, and building capacity at national level to enhance the way HCW is dealt with in low-income countries (WHO 2016).

1.2 Burden of Health Care Waste in Uganda and Associated Risks

In Uganda, infectious diseases such as HIV and hepatitis B and C constitute 60 percent of the nation's disease burden (Ministry of Health [MOH] 2015) and the prevalence of noncommunicable diseases is rising rapidly (MOH 2014).

Due to the high disease burden, communities across the country are seeking high-quality health services. In response, the MOH, in collaboration with development partners, is scaling up in the health care sector, taking services to all districts, while at the same time introducing additional services in lower-level health facilities and at community service points (MOH 2014). In addition, the National Health Policy II (Uganda MOH 2010) recognizes the private sector as a key player in service provision, contributing about 50 percent of service provision, HIV counseling and testing, services for elimination of mother-to-child transmission HIV (eMTCT), voluntary medical male circumcision (VMMC), laboratory monitoring, malaria control via indoor residual spraying, mass vaccinations (with newly introduced vaccines), screening and treatment for hepatitis B, and directly observed therapy, short course (DOTS) for TB. These programs are generating ever-increasing volumes of HCW.

However, the Uganda National HIV Indicator Survey (Uganda MOH 2014), signifies that the nation's health care infrastructure lacks the capacity to handle this volume and the current data on HCW volume generated by health facilities shows it to be increasingly large. Infectious waste may lead to the transmission of more than 30 significant pathogens, including typhoid, hepatitis B and C, Escherichia coli, and staphylococcus aureus (Binaya 2014). According to data collected by private sector waste company Green Label Services Ltd (GLSL) in eastern Uganda, the majority of HCW in Uganda is generated by hospitals.

A series of assessments on practices in HCW management in the nation's health facilities indicates that they are failing to cope with the situation. For example, between 40 and 90 percent of facilities use unacceptable methods of HCW treatment and disposal (AIDSTAR-One 2009). More recent data from the Site Improvement Through Monitoring System (PEPFAR 2015), reveals very low scores for facilities' HCW management,˙ with most burning in the open or in a shallow pit for final disposal.

A small proportion of facilities are using small-scale incinerators, most of which fail to meet recommended environmental temperature and smoke emission requirements. This may contribute to pollution that exposes humans to cancers and birth defects (Uganda MOH 2009).

1.3 Findings of Recent Assessments and Evaluations

A baseline assessment of HCW management practices in 20 project districts in Uganda (AIDSTAR-One 2013), found that 42 percent of evaluated facilities were not segregating waste at all; needlestick injuries among health workers were uncommon; and that crude methods of final disposal—dumping, open burning, burning in a shallow pit, and low-temperature incineration— were common. AIDSTAR-One used the findings of the assessment to generate a national plan that recognizes a pollution ban and development of environmentally friendly waste disposal systems as high-priority strategies to safeguard communities, health workers, and the environment. To be sustainable, these strategies must be implemented within a sound policy environment and an efficient HCW management system.

Although individual and national efforts have attempted to establish systems for treating and disposing HCW, they have not been well guided, and in the end facilities have chosen less-than-optimal methods for final waste disposal. Technology used in the country, including low- to medium-temperature incineration, is adding to the problem by polluting the environment, and auditors are increasingly concerned about the levels of pollution contributed by the health sector (Office of the Auditor General in Uganda 2015).

However, many stakeholders, including WHO, USAID, the Japan International Cooperation Agency, and World Bank, are willing to help Uganda realize high HCW management standards but do not have reliable information to guide decision-making, especially when it comes to selecting the most appropriate technology for HCW treatment and disposal. Efforts have focused on system strengthening via capacity building, supporting the supply of HCW management commodities, and enforcing waste segregation. However, health facilities' access to HCW treatment and disposal remains a challenge.

1.4 Non-Incineration Technology

1.4.1 Non-Incineration Technology As Potential Solution To Waste Disposal In Southwestern Uganda

Through AIDSFree, USAID will procure non-incineration equipment for a centralized waste treatment and disposal plant in southwestern Uganda. This assessment collected information on characteristics of waste to facilitate data-driven decisions on the regional health facilities' needs and the type of technology that would be appropriate to meet them.

1.4.2 Factors To Consider When Selecting A Non-Incineration Technology

Factors to consider when selecting waste treatment technology can be grouped into two categories; nontechnical and technical.

Nontechnical factors include stage of development of the nation's waste management policy and system; ability to comply with environmental regulations; the licensing situation; human resources and personnel competence; costs and resources; geographical and geological conditions; and cooperation among facilities.

Technical factors include waste characteristics; scale of technology application; maturity and robustness of the technology; field of technology application; treated product characteristics; anticipated future needs; facilities' complexity and ease of maintenance; volume reduction; secondary waste compatibility with existing processes; state of research and development; safeguards and safety;

and potential for intrusion. Some of these factors—such as waste characteristics—are better assessed at health facility level.

1.4.3 Preferred Methods For Characterizing Health Care Waste

An understanding of the composition of hospital waste is fundamental for choosing the best alternatives for disposal. Thorough characterization of waste prevents accidents and exposure to waste by handlers, including operators of treatment equipment.

According to WHO in 2007 waste should be characterized according to material and its composition (e.g., paper, plastic, glass, metal, cloth, gauze); the risk posed by the waste or its classification (e.g., sharps or infectious, pathological, chemical, radioactive, or non-risk waste); and by waste generation rates (2007). Waste with single-constituent material is easier to handle than waste with several constituents, as some materials may damage technology. Some chemicals can damage equipment or cause harm to exposed waste handlers, equipment operators, transporters, or the environment, whether through direct contact or inhalation or indirectly through the food chain.

2.0 PROBLEM STATEMENT

A rapidly growing population with high infectious disease prevalence requires scale up high-impact interventions to prevent, diagnose, treat, and rehabilitate affected communities, which brings with it ever-increasing volumes of HCW (Uganda MOH-HMIS 2010–2015). Per USAID SIMS reports, waste generated is often managed using methods that pose risks to health workers, patients, communities, and the environment.

In developing countries, there are many solutions to the problem of waste treatment and disposal, but the appropriateness of most of these solutions to specific waste situations in Uganda has not been well studied. USAID has provided support to establish a sustainable, long-lasting solution for waste treatment and disposal in southwestern Uganda (AIDSFree, 2016), but the type of technology to be installed must be tailored to the region's waste characteristics, environmental concerns, and legal requirements (United Nations Environment Programme, 2012).

There are 13 districts in southwestern Uganda: Rukungiri, Kanungu, Bushenyi, Mbarara, Kisoro, Isingiro, Ibanda, Sheema, Mitooma, Kiruhura, Kabale, Ntungamo, and Buhweju The region's population of 3,361,756 is served by 607 health facilities—436 level II health centers (HCs); 128 level III HCs; 28 level IV HCs; 13 general hospitals; and two regional referral hospitals (Uganda MOH-Inventory 2015). In total, 309 of the facilities are government owned; 140 owned by private sector concerns; and 103 owned by private not-for-profit service providers (Uganda MOH-Inventory 2015).

For a solution to be appropriate and sustainable, comprehensive research is required to better understand:

1. Various streams, rates, and quantities of waste generated.
2. Products and supplies purchased by facilities.
3. Physical, chemical, and morphological characteristics of the waste.
4. Future population projections.
5. Plans for implementing aggressive waste and pollution prevention.
6. Existing efforts to recycle selected materials.
7. Waste segregation practices among waste generators.
8. Types of risks posed by different categories of waste.
9. Environmental requirements for the selected technology.
10. Initial and recurrent costs involved.
11. Impact on society and the environment (e.g., water, energy, air, and noise pollution).
12. Acceptability to all stakeholders.

The assessment documented over the following pages was conducted starting March 2-9, 2016 to generate information to evaluate suitable waste treatment technologies, develop equipment specifications, and establish operating parameters for HCW treatment.

3.0 OBJECTIVES

3.1 General Objective

The study was intended to determine the characteristics of HCW generated at health facilities in Mbarara District to generate information that the district health committee and various stakeholders will use to promote a healthy environment among the people of Mbarara.

3.2 Specific Objectives

1. Determine quantities of HCW generated at different levels of health service delivery in Mbarara District.
2. Determine physical characteristics of HCW generated in the southwestern region; material constituents, moisture content, bulk density, and calorific value.
3. Identify different types of chemicals that contaminate HCW generated in Mbarara.
4. Establish whether the current levels of waste segregation favor recycling of materials as well as use of special waste treatment technology.

4.0 METHODOLOGY

4.1 Study Area

The study was conducted at Mbarara District, which is located in the southwestern part of Uganda. It boarders Ibanda and Kiruhura districts to the north, Kiruhura and Isingiro districts to the east, Isingiro and Ntungamo districts to the south, and Bushenyi district to the west. Mbarara covers 1,846.4 sq. km. (Mbarara District Local Government 2009).

4.2 Study Design

This was a cross sectional study conducted in February 2016 in Mbarara District facilities that provide health service delivery to the people.

4.3 Study Population

All health facilities that offered health services to the people.

Inclusion criteria: All government health facilities; i.e., regional referral hospitals, general hospitals, health facilities at lower levels with the highest outpatient and inpatient attendance, and service delivery points.

Exclusion criteria: Health facilities with low outpatient and inpatient attendance, private nonprofit health facilities, and private for-profit health facilities.

4.4 Sample Selection Criteria and Sample Size

Selection of the districts and service delivery points

Mbarara District was selected as the assessment site because of its diverse levels of health facilities, including a regional referral hospital (RRH), a general hospital, and levels II, III, and IV health centers (HCs).

- RRH: Purposeful selection was used, because there was only one hospital of this type in the district.
- General hospital and health facilities at lower levels: the hospital and the lower-level facilities with the highest outpatient and inpatient attendance were selected.
- Service delivery points: all service delivery points were included.

4.5 Data Collection

4.5.1 Determination of Quantities of Waste Generated at Different Levels of Health Facilities

To determine quantities of waste generated in a health facility, health workers were oriented on waste segregation, and color-coded waste bins made available at all service delivery points. In addition, job aids were placed at all service delivery points to remind health workers how to segregate waste.

When containers were three-quarters full, waste was collected by a trained waste handler and delivered to a designated area for weighing. A supervisor weighed and recorded the weight of the waste (in kilograms) by department and service delivery point. The supervisor also recorded the class of waste weighed (e.g., infectious, highly infectious, sharps, pharmaceutical waste).

The weighing was conducted over seven consecutive days. Next, the total weight of waste per level of health facility was obtained by adding the weight of waste in each class per day.

4.5.2 Determination of Physical Characteristics of Aggregated Waste

Material constituents

To determine HCW material constituents, the waste of different classes collected from different service delivery points was poured on a plastic sheet placed on top of cardboard at the back of the health facility. The different materials were then raised with a pair of tongs and placed in buckets labeled with names of the different potential waste materials. The waste was then weighed by type of material. To eliminate the risk of sorting infectious waste, only nonhazardous waste was sorted. Every service delivery point was assessed for the material constituents of its waste.

The weighing was conducted over seven consecutive days. Next, the weight of the waste per material was obtained by adding the daily weights over the seven days, then divided by seven to yield the average daily weight per material per facility.

Moisture content of generated waste

To determine the HCW moisture content, three classes of segregated waste were considered: highly infectious waste, infectious waste, and pathological waste.

Assuming the sample estimates are normally distributed, the sample size needed was obtained from the formula:

$$n = 4Z_{\propto}^{2}P(1-P)/(W^{2})$$

Where n = sample size, P = expected proportion (in proportion of one; if 20 percent, P=0.2); W = precision/total width of confidence interval (in proportion of one; if 50 percent, d=0.5); and Z = normal distribution at 95 percent confidence interval (1.96).

After applying this formula, it was established that 32 bins was the sample size required to establish the level of moisture content. A random sample of 32 bins from the selected health facilities per level was generated (Table 1).

Table 1. Number and Percentage of Waste Samples Taken for Determining Moisture Content by Level of Health Facility

Level of Health Facility	Number of Waste Samples Taken for Determination of Moisture Content (Frequency)	% (N = 32)
Nyamityobora HC II	1	3.13
Rubindi HC III	3	9.38
Bwizibwera HC IV	5	15.63
Ruharo General Hospital	7	21.88
Mbarara RRH	16	50.00
Total	32	100.00

Calorific value of generated waste

One gram of each of the 32 samples used for determining moisture content were subjected to calorimetry to determine their calorific value.

Bulk density

Density is defined as mass per unit volume. If the volume under evaluation is not tampered with (for example, volume occupied by segregated waste before any volume reduction method is applied), the density can be referred to as bulk density. Bulk density helps in deriving appropriate sizes/capacity of waste bins and liners, transport vehicles, storage rooms, and capacity/volume of waste treatment technology.

Calorific value

Calorific value is defined as the amount of heat released for every unit dry mass of a substance burnt. Substances with high calorific value produce more heat than those with low values. High amounts of heat produced by dry waste provide additional fuel for incinerating waste, reducing overall costs for fuel. If the released heat is significant, energy/heat recovery options can be considered. High calorific measurement implies that the waste could be suitable for incineration combined with energy recovery.

4.5.3 Types of Chemicals That Contaminate Health Care Waste

A list of chemicals that contaminate HCW was generated, and departments that use the chemicals identified. The departments were visited to identify service delivery points that use the chemicals and to locate the waste bins where the chemicals are disposed.

4.5.4 Whether Current Waste Segregation Levels Favor Recycling and Use Special Waste Treatment Technology

Waste segregation practices for selected service areas were observed to assess whether waste was being segregated according to MOH standards. Observations were recorded for analysis.

4.6 Data Collection Tools

Data collection tools for the assessment were developed by a team of HCW management experts. These were reviewed and piloted to determine their applicability and refined and used for data collection. A sample of the data collection tools is provided in the annex.

4.7 Data Entry

For quantitative data, double data entry was used; data were entered into Excel sheets and checked manually for accuracy then the two sets of data were compared for consistency.

4.8 Field Activities

4.8.1 Preliminary Visit to the District and Selected Facilities

The purpose of the preliminary visit was to:

- Inform the district authorities of the planned activity.
- Select participating health facilities based on the number of clients served.
- Code service delivery areas and identify waste segregation commodity needs.
- Screen waste handlers and identify training needs.

4.8.2 Selection of Participating Health Facilities

Based on data from the health management information system, the facilities at different levels with the highest patient load were:

- Mbarara RRH
- Ruharo General Hospital
- Bwizibwera HC IV
- Rubindi HC III
- Nyamityobora HC II

4.8.3 Service delivery areas and commodities

The service areas within the selected health facilities were identified and actual requirements in terms of waste bins noted. It was generally observed that the number of waste bins was limited.

4.8.4 Participating personnel

At each facility, the following personnel took part in the initial assessment:

- Facility supervisor
- Waste handlers
- Storekeeper/store personnel

A supervisor was chosen for each facility. His or her role included:

- Identifying and mapping all areas in the health facility that generate waste and making a comprehensive list of all the areas.
- Quantifying the number of color-coded waste bins and liners (by color code) and submitting these to the field coordinator.
- Identifying a designated area for receiving waste from service delivery points.
- Securing adequate storage space for all waste that will be received.
- Training waste generators and health workers in waste segregation.
- Supporting waste handlers in collecting and weighing waste.
- Entering data correctly into the data collection sheets.
- Identifying waste for estimation of moisture content.

The role of the waste handler was:

- Distributing color-coded waste bins with accompanying liners to all waste generation points.
- Checking frequently to establish whether waste bins are three-quarters full.
- Removing all waste bins that are three-quarters full, taking them to a designated place at the back of the health facility, and handing it over to the person weighing the waste (the supervisor).
- Replacing the removed waste bin with a similar (fresh) waste bin.
- Supporting the supervisor in weighing the waste.

The role of the store personnel was to provide information about:

- Commodities for HCW that is routinely provided.
- Strategies for minimizing waste as they order items.
- Expired items, quantities, and methods of disposing of them.

4.8.5 Pre-Screening Waste Handlers and Identifying Training Needs

- Waste handlers at the facilities were screened to establish those who could take part in the assessment. Because waste is processed in shifts, it was agreed that the waste handler who was on duty would take part in the assessment.
- Waste handlers had some protective gear, notably gumboots and an overcoat. Heavy-duty gloves were not available.
- Waste handlers had no formal training but were guided through what they needed to do for their work.
- Some waste handlers were vaccinated against hepatitis B; others were not.

4.8.6 Conclusion of Initial Field Work

Sites to participate in the assessment were chosen. Service delivery areas were selected at all the participating health facilities and the waste commodities gaps were identified. Screening revealed the need to train waste handlers before the assessment and the gaps in protective wear flagged.

4.8.7 Health Worker Training

Before conducting the assessment, all health workers in participating health facilities were trained on HCW management. This four-day training covered:

- Categories of HCW
- Waste segregation
- Waste collection
- Treatment and final disposal of waste

4.9 Limitations and Challenges

Several limitations and challenges to the study were identified:

- Waste segregation by health facility staff was a challenge because some facilities had a limited number of waste bins and health workers, although trained on waste segregation, had not yet achieved high levels of compliance at the time of data collection.
- Special clinic days, such as circumcision clinics, affect the volume of waste generated at some facilities. Seasonal variations in disease patterns may also have an effect.
- Due to the limited quantities generated, pharmaceutical waste was not included in the study.
- Failure to assess features of chemical waste was also a limitation to the study.

5.0 FINDINGS

5.1 Sample Size and Health Facility Information

All five targeted high-volume health facilities participated in the assessment: Mbarara RRH, Ruharo General Hospital, Bwizibwera HC IV, Rubindi HC III, and Nyamityobora HC II. Nyamitobola HC level II is purely an outpatient facility; the rest have provision for admission of patients with varying bed capacity, as elaborated below. With exception of level II, all levels offer laboratory services.

5.1.1 Mbarara Regional Referral Hospital

Owned by the Government of Uganda, this hospital has a bed capacity of 451, an average monthly outpatient department (OPD) attendance of between 13,000 and 15,000, an average monthly inpatient attendance of 5,000, and a 74 percent average monthly bed occupancy over a year.

Waste segregation and commodities

Before the assessment, there had been no waste segregation because of shortage of waste bins. Commodities supplied through National Medical Stores—safety boxes, bin liners, and waste bins—were reported to be available in limited quantities most of the time. It was observed that during data collection, waste bins, liners, and sharps boxes were available in most of the service areas (80.6%).

Screening of waste handlers

At this level, it was reported that 56 percent of the nine sampled waste handlers had had no HCW management training. Further, 78 percent had not been vaccinated against hepatitis B. Most reported having been provided with gumboots, gloves, and overalls/overcoats. More than half reported needlestick injuries, and it was not clear to 44 percent of them whether a system for reporting exposures was in place.

5.1.2 Ruharo General Hospital

This facility, owned by Church of Uganda has 104 beds and had an average OPD attendance of 615, an average inpatient attendance of 364, a 33.7 percent bed occupancy per month, and 626 laboratory clients per month over the year preceding the study.

Waste segregation practices and commodities

There was an effort to set up a system for segregating HCW according to categories of risk, but most (71%) service delivery areas were not fully compliant. Deeper analysis of waste segregation practices in selected service areas revealed that although waste bins in the appropriate colors were available at most (71.4%) service delivery areas, there were no accompanying color-coded liners.

The hospital had purchased PPE and routinely provided it to the waste handlers. Final HCW disposal was done through open burning.

Screening of waste handlers

Two of three sampled waste handlers had been trained on HCW management. All had been vaccinated and were routinely provided with PPE (boots, gloves, and aprons).

5.1.3 Bwizibwera Health Centre IV

This Government of Uganda-owned facility has a 46-bed capacity and had an average monthly OPD attendance of 1,366 over the year preceding the study.

Waste segregation and commodities

No waste segregation had been undertaken prior to the study because of a limited number of waste bins. However, waste bins, liners, and safety boxes were provided in preparation for the study. At the time of the assessment, most sampled service areas (80%) had waste bins with the appropriate color-coded liner. Sixty percent of the areas sampled during the study were segregating waste. Waste handlers here had no PPE.

Screening of waste handlers

Of the two sampled waste handlers, one had been trained and vaccinated against hepatitis B and the other not. Both had been provided with gumboots, but no other PPE. The handlers reported that a system was in place for reporting needlestick injuries.

5.1.4 Rubindi Health Centre III

This Government of Uganda-owned facility has six beds and, per month, over the year preceding the study, had an average attendance of 692 in the OPD and 18 inpatients.

Waste segregation and commodities

Prior to the study, waste bins and liners were available in the facility store but not used in some service delivery areas. At the time of the assessment, all sampled service areas had waste bins with accompanying color-coded liners. Sharps boxes were available in areas with injection waste. An effort had been made to segregate other types of waste in all service areas according to recommended color codes. Waste handlers were routinely provided with gumboots.

Screening of waste handlers

One sampled waste handler at this facility reported having been trained but did not know about vaccination against hepatitis B. He had been provided with gumboots and gloves and reported that a system for reporting needle stick injuries was in place.

5.1.5. Nyamityobora Health Centre II

In this Government of Uganda-owned facility, the average monthly OPD attendance was 303 over the year preceding the study.

Waste segregation and commodities

All sampled service areas had waste bins with the appropriate color-coded liners. However, in one of the three areas, waste was not placed in appropriate color-coded waste bins.

Screening of waste handlers

One sampled waste handler at this facility reported having been trained, but had not been vaccinated against hepatitis B. He reported having been provided with gumboots and an apron.

5.2 Quantities of Waste Generated

The table below indicates the total waste that was generated over a period of one week of facility operations.

Table 2. Total Waste Generated by Selected Facilities in Mbarara District Over One Week

Waste Classification	Total Kilograms of Waste Generated						% of Facility HCW Generated	Overall Average Waste Generated (kg/day)
	Mbarara RRH	Ruharo General Hospital	Bwizibwera HC IV	RubindiHC III	NyamityoboraHC II	Total		
Nonhazardous	**202.25**	**12.58**	**34.57**	**14.68**	**1.06**	**265.14**	**25.78**	**37.88**
Hazardous	**649.22**	**54.95**	**52.24**	**4.14**	**2.64**	**763.19**	**74.22**	**109.03**
Hazardous Waste by Category of Risk								
Sharps	54.12	4.16	3.16	0.86	0.77	63.07	6.13	9.01
Infectious	222.14	22.06	17.11	2.76	0.59	264.66	25.74	37.81
Highly infectious	371.32	28.73	31.09	0.22	0.39	431.75	41.99	61.68
Pharmaceutical	0.00	0.00	0.88	0.3	0.89	2.07	0.20	0.30
Other	1.64	0.00	0.00	0.00	0.00	1.64	0.16	0.23
Total Waste	**851.47**	**67.53**	**86.81**	**18.82**	**3.7**	**1,028.33**	**100.00**	**146.90**
Waste Physical Characteristics								
Paper	45.05	7.82	15.37	4.3	1	73.54	27.95	10.51
Glass	13.60	0.00	0.00	0.00	0.00	13.60	5.17	1.94
Plastic	81.46	2.67	13.52	2.88	0.03	100.56	38.22	14.37
Metal	1.18	0.00	0.00	0.00	0.00	1.18	0.45	0.17
Tissue	—	—	—	—	—	—	—	—
Cotton/gauze	10.797	1.63	0.00	0.00	0.00	12.43	4.72	1.78
Other	55.645	0.89	5.29	0.00	0.00	61.83	23.50	8.83
Total	**207.73**	**13.01**	**34.18**	**7.18**	**1.03**	**263.13**	**100.0**	**—**

A total 1,028 kg of nonhazardous HCW was generated at the five facilities that participated in the assessment. Highly infectious waste contributed the highest proportion of waste (at 41.99%), followed by nonhazardous waste (25.74%), and infectious waste (25.4%). Sharps waste (6.13%), was consistent with earlier studies that revealed that sharps waste contributed about 5 percent of all waste. Although the assessment was conducted when safe male circumcision was ongoing, metallic scrap from used surgical instruments had not been handed over for disposal.

5.3 Proportions of Waste Contributed by the Different Health Facilities

Mbarara RRH contributed 82.8 percent of total waste generated, followed by Bwizibwera (at 8.44 percent; see Table 3).

Table 3. Proportions of Waste

Waste Generated (kg)	Mbarara RRH	Ruharo General Hospital	Bwizibwera HC IV	Rubindi HC III	Nyamityobora HC II	Total
Total for 7 Days	851.47	67.53	86.81	18.82	3.7	1,028.33
Proportion of Waste (%)	82.8	6.57	8.44	1.83	0.36	100

5.4 Waste Generation Per Facility

5.4.1 Mbarara Regional Referral Hospital

Table 4. Waste Generated at Mbarara RRH Over One Week

Waste Classification	Total Mass for 7 Days (kg)	Average Kg Waste Generated Per Day	%
Nonhazardous	**202.25**	**28.89**	**23.75**
Hazardous	**649.22**	**92.75**	**76.25**
Hazardous Waste by Category of Risk			
Sharps	54.12	7.73	6.36
Infectious	222.14	31.73	26.09
Highly infectious	371.32	53.05	43.61
Pharmaceutical	0.00	0.00	0.00
Other	1.64	0.23	0.19
Total Waste	**851.47**	**121.64**	**100.00**
Waste Physical Characteristics			
Paper	45.05	6.44	21.69
Glass	13.60	1.94	6.54
Plastic	81.46	11.64	39.21
Metal	1.18	0.17	0.57
Tissue	—	—	—
Cotton/gauze	10.80	1.54	5.20
Other	55.65	7.95	26.79
Total	**207.73**	**29.68**	**100.00**

Mbarara RRH produced the highest quantity of waste, with an average waste generation rate of 122 kg per day. Further analysis of the results shows that nonhazardous waste constituted 23.75 percent of total waste.

With an average bed occupancy rate of 334 of 451 beds (74%), the waste generation rate per bed per day was calculated as follows:

$$122 \div 451 \times 0.74 = 0.36 \text{ kg/bed/day}$$

Nonhazardous waste was further analyzed to review the material composition. Plastics constituted about 11.64 kg per day, or 39.21 percent of all nonhazardous waste. Paper constituted 6.44 kg per day, or 21.69 percent of the nonhazardous waste generated. The two materials comprised 60.9 percent of the general waste.

5.4.2 Ruharo General Hospital

Table 5. Waste Generated at Ruharo General Hospital

Waste Classification	Total Mass for 7 Days (kg)	Average Kg Waste Generated Per Day	%
Nonhazardous	**12.58**	**2.10**	**18.63**
Hazardous	**54.95**	**7.85**	**81.37**
Sharps	4.16	0.69	6.16
Infectious	22.06	3.68	32.67
Highly infectious	28.73	4.79	42.54
Pharmaceutical	0.00	0.00	0.00
Other	0.00	0.00	0.00
Total Waste	**67.53**	**11.26**	**100.00**
Waste Physical Characteristics			
Paper	7.82	1.30	60.11
Glass	0.00	0.00	0.00
Plastic	2.67	0.45	20.52
Metal	0.00	0.00	0.00
Tissue	—	—	—
Cotton/gauze	1.63	0.27	12.53
Other	0.89	0.15	6.84
Total	**13.01**	**2.17**	**100.00**

The Ruharo Hospital waste generation rate was 11.2 kg per day. With 100 percent bed occupancy, the waste generation rate per bed per day was an estimated 11.2 for each of the 104 beds, or 0.11 kg per bed per day. Further analysis revealed nonhazardous waste contributed 18.6 percent of the total waste.

The nonhazardous waste was then analyzed. A review of the material constituents revealed that paper and plastics constituted 80.65 percent of the general waste in the proportions of 60.11 percent and 20.52 percent respectively.

5.4.3 Bwizibwera Health Centre IV

Table 6. Waste Generated at Bwizibwera HC IV

Waste Classification	Total Mass for 7 Days (kg)	Average Kg Waste Generated Per Day	%
Nonhazardous	**34.57**	**5.76**	**39.82**
Hazardous	**52.24**	**7.46**	**60.18**
Sharps	3.16	0.53	3.64
Infectious	17.11	2.85	19.71
Highly infectious	31.09	5.18	35.81
Pharmaceutical	0.88	0.15	1.01
Other	0.00	0.00	0.00
Total Waste	**86.81**	**14.47**	**100.00**
Waste Physical Characteristics			
Paper	15.37	2.56	44.97
Glass	0.00	0.00	0.00
Plastic	13.52	2.25	39.56
Metal	0.00	0.00	0.00
Tissue	—	—	—
Cotton/gauze	0.00	0.00	0.00
Other	5.29	0.88	15.48
Total	**34.18**	**5.70**	**100.00**

Bwizibwera Hospital generated the second-highest quantity of waste, with an average waste generation rate of 14.47kg per day. With an average OPD attendance of 46 per day, the daily per-patient waste generation was estimated as 0.31 kg (i.e., 14.5kg per day/46 patients per day).

Nonhazardous waste constituted 39.82 percent of total waste. Of this waste, paper and plastics comprised 44.97 percent and 39.56 percent, respectively, for a total of 89.53 percent of the nonhazardous waste.

5.4.4 Rubindi Health Centre III

Table 7. Waste Generated at Rubindi HC III

Waste Classification	Total Mass for 3 Days (kg)	Adjusted Mass for 7 Days (kg)	Average Waste Per Day (kg)	%
Nonhazardous	**7.34**	**14.68**	**2.45**	**78.00**
Hazardous	**2.07**	**4.14**	**0.59**	**22.00**
Hazardous Waste by Category of Risk				
Sharps	0.43	0.86	0.14	4.57
Infectious	1.38	2.76	0.46	14.67
Highly infectious	0.11	0.22	0.04	1.17
Pharmaceutical	0.15	0.30	0.05	1.59
Other	0.00	0.00	0.00	0.00
Total Waste	**9.41**	**18.82**	**3.14**	**100.00**
Waste Physical Characteristics				
Paper	4.30	8.60	1.43	59.89
Glass	0.00	0.00	0.00	0.00
Plastic	2.88	5.76	0.96	40.11
Metal	0.00	0.00	0.00	0.00
Tissue	—	0.00	0.00	—
Cotton/gauze	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.00
Total	**7.18**	**14.36**	**2.39**	**100.00**

Rubindi HC III had an average waste generation rate of 3.14 kg per day, and with an average daily OPD attendance of 23, the waste generation rate per patient per day could be estimated as 0.14 kg per patient per day (i.e., 3.14 kg per 23 patients).

Analysis of the waste revealed that nonhazardous waste contributed 78 percent of the total. Paper and plastics constituted 59.89 and 40.11 percent of the nonhazardous waste, respectively, comprising virtually 100 percent of the nonhazardous waste.

5.4.5 Nyamityobora Health Centre II

Table 8. Waste Generated at Nyamityobora HC II

Classification of Waste	Total Mass for 5 Days (kg)	Average Waste Generated Per Day (kg)	%
Nonhazardous	**1.06**	**0.21**	**28.65**
Hazardous	**2.64**	**0.38**	**71.35**
Hazardous Waste by Category of Risk			
Sharps	0.77	0.15	20.81
Infectious	0.59	0.12	15.95
Highly infectious	0.39	0.08	10.54
Pharmaceutical	0.89	0.18	24.05
Other	0.00	0.00	0.00
Total Waste	**3.70**	**0.74**	**100.00**
Waste Physical Characteristics			
Paper	1.00	0.20	97.09
Glass	0.00	0.00	0.00
Plastic	0.03	0.01	2.91
Metal	0.00	0.00	0.00
Tissue	—	—	—
Cotton/gauze	0.00	0.00	0.00
Other	0.00	0.00	0.00
Total	**1.03**	**0.21**	**100.00**

Nyamityobora HC II generated an average 0.74 kg of waste per day. With an average daily OPD attendance of 10, the daily per person waste generation rate was 0.074 (i.e., 0.74 kg/10 patients). Nonhazardous waste comprised 28.65 percent of the total waste.

Paper constituted 97.09 percent of the general waste; plastics 2.91 percent. The two substances combined comprised 100 percent of the general waste.

5.5 Determination of Moisture Content of Waste

The moisture content of each of the 32 samples analyzed was obtained, and the average moisture content was calculated. The average moisture content of the waste was 46.2 percent, with a standard deviation of 0.19, based on the 32 samples. Moisture content ranged from 6.29 percent to 73.73 percent.

Table 9. Range of Moisture Content for Sampled Waste

Range of Moisture Content (%)	Number of Samples
>70	8
60–69	2
50–59	7
40–49	7
30–39	0
20–29	0
10–19	6
0–9	2

5.5.1 Calorific Value Of Waste

The heating value of the infectious waste ranged between 2.84 kcal/g to 7.24 kcal/g (Table 10).

Table 10. Range of Heating Value for Sampled Waste

Range of Heating Value (kcal/g)	Number of Samples
>7	5
6–6.99	10
5–5.99	2
4–4.99	6
3–3.99	8
2–2.99	1
1–1.99	0

The average calorific value was 5.3 kcal/g—high compared to a global average value of 3.6 kcal/g (United Nations Environment Programme 2012).

5.6 Chemicals That Contaminate Health Care Waste

Chemical composition is a general guide to thermal treatability, along with heating value. This survey did not include chemical assessment; it was limited to identification of the service areas that use the chemicals.

6.0 DISCUSSION

6.1 Total Waste Generated by Category of Hazard

Broadly, waste is classified into two major categories: hazardous and nonhazardous. Exposure to hazardous waste risks harm from infectious and highly infectious waste, which may contain blood-borne pathogens. Sterilization methods (i.e., non-burning methods) will render infectious and highly infectious waste pathogen-free. Previous studies undertaken worldwide indicate that with proper waste segregation, the proportion of hazardous waste generated at a health facility should be between 75 and 90 percent (United Nations Environment Programme [UNEP] 2012).

In this study, the total proportion of nonhazardous waste was about 25.8 percent—low compared to the expected proportion (UNEP 2012), suggesting poor waste segregation. Failure to segregate waste makes non-incineration disposal methods unnecessarily expensive; it fills up autoclaving chambers with material that could have been recycled or disposed at a municipal landfill. To prepare to switch to non-incineration technology, the district needs to increase waste segregation compliance.

6.2 Hazardous Waste

Among facilities studied, Mbarara RRH generated the largest proportion of hazardous HCW (82.8%), with the others combined contributing 17.2 percent. When citing any centralized waste treatment facility, proximity to Mbarara RRH is advisable to reduce transport costs. Lower-level facilities are not generating enough waste to warrant their own treatment plants and would benefit from a centralized system with licensed service providers transporting and disposing their waste.

6.2.1 Nonhazardous Waste

Nonhazardous waste by quantities

Mbarara and Ruharo hospitals, Bwizibwera HC IV, Rubindi HC III, and Nyamityobora HC II contribute 24 percent, 18 percent, 40 percent, 78 percent, and 29 percent of nonhazardous waste, respectively. The proportions for Mbarara, Ruharo, Bwizibwera, and Nyamityoboraare are below the expected 75–90 percent noted above, again pointing to poor waste segregation. The 78 percent figure at Rubindi signals good waste segregation, and at 40 percent, Bwizibwera shows itself to have made a fair attempt. Segregation practices at other facilities need improvement. Less-than-optimal waste segregation may have affected the proportions of hazardous and nonhazardous waste.

The volume of waste generated at Bwizibwera HC IV exceeds that generated at Ruharo General Hospital. This may reflect the extra services provided at the health unit or the possibility that factors such as user fees limit hospital attendance and thus service provision, resulting in a lower-than-expected volume of waste. Low waste generation levels could also reflect proximity of this hospital to others providing similar services and thus a lower patient load. The MOH should review the range of services provided at Ruharo and consider broadening its scope.

6.2.2 Nonhazardous Waste By Types Of Materials

Nonhazardous waste was further analyzed by material type to determine whether quantities generated could support local recycling innovations of paper, glass, plastic, and metal. Findings revealed that with improved waste segregation, quantities of paper and plastics might warrant setting up recycling operations.

6.3 Waste Generation Rates

Average waste generation rates in the hospitals were lower than for the daily 2 kg per bed described by UNEP (2012). The lower level may result from collection of some waste, especially general waste, outside the mainstream waste collection system. The hospitals' services may also differ—health facility waste volume increases as the number of services increases. Lower waste generation rates imply that the facilities are not ready for individualized or on-site treatment facilities, but they would benefit from buying into centralized waste treatment and disposal services.

For HCs II, III, and IV, the average number of outpatients per day was used to estimate the waste generation rate (Table 11).

Table 11. Waste Generation Rates per Health Facility

Health Facility	Daily Waste Generation Rate
Nyamityobora HC II	0.074 kg/patient
Rubindi HC III	0.14 kg/patient
Bwizibwera HC IV	0.31 kg/patient
Ruharo General Hospital	0.11 kg/bed
Mbarara RRH	0.36 kg/bed

Table 12. Waste Generation Rate for All Facilities in Mbarara District

Facility Level	Daily Infectius Waste Generation Rate (kg)	Number of Beds	Percent Bed Occupancy Per Month	Daily Waste Generation Rate (kg/bed/day)/ (kg/patient/day)	Estimated Bed Capacity for the Level of Facility	Daily Waste Generation Rate (kg/day)	Number of Facilities at This Level	District Daily Total Waste Generated (kg)
RRH	92.7	451	0.74	0.28	500	138.88	1	138.88
General Hospital	9.1	104	0.34	0.09	100	8.75	7	61.25
HC IV	8.7	46	0.46	0.19	46	8.70	4	34.80
HC III	0.68	6	0.05	0.03	18	0.68	15	10.20
HC II	0.54	0.00	N/A	0.054	0	0.54	40	21.60
TOTAL								266.73

6.4 Moisture Content

Average HCW moisture content was 46.2 percent, with a standard deviation of 0.19, based on 32 samples. This average is high compared to the expected average; that is, 15 percent by weight (United Nations Environment Programme, 2012). High moisture content would make the waste suitable for autoclaving but less suitable for incineration.

6.5 Calorific Value

Average calorific value of the samples measured was 5.3 kcal/g. This is high compared to the average value, 3.6 kcal/g, measured by UNEP (2012).

6.6 Bulk Density

The average bulk density of different HCW components at Mbarara RRH was measured (Table 13). HCW bulk density determines the volume of the autoclave that will be required for waste sterilization.

Table 13. Bulk Density of Components of Health Care Waste at Mbarara Regional Reference Hospital

Component	Average Bulk Density (kg/m^3)	Range of Bulk Density (kg/liter)
General waste	182	0.02–0.48
Infectious waste	176	0.02–0.79
Highly infectious waste	608	0.01–6.18
Sharps	215	0.02–0.42
Paper	92.7	0.01–0.48
Plastics	173	0.01–0.72

7.0 CONCLUSION AND RECOMMENDATIONS

The high-volume health facilities selected for study in Mbarara District generated significant quantities of HCW, with the RRH generating the bulk of it (more than 80%). Not all facilities generated the critical volume of waste that would warrant installation of their own treatment and disposal facilities, leading to the conclusion that all would benefit from access to shared, centralized waste treatment and disposal facilities. The current less-than-optimal levels of waste segregation will make treatment and disposal of infectious and highly infectious waste unnecessarily expensive.

Quantities of paper and plastic waste generated at the health facilities were significant, and efforts at setting up recycling centers would be beneficial. The volume of recyclable materials is likely to increase as waste segregation improves.

The high moisture content of the facilities' waste favors autoclaving as a treatment method since moisture will accelerate steam penetration. Although the materials have a high calorific value, their high moisture content (wetness) makes treatment by incineration a less favorable option. The high moisture will tend to lower the burning temperature. The bulk density registered calls for large-volume equipment.

The following recommendations are based on the assessment findings.

1. Waste segregation practices at health facilities should be improved. Increased HCW training and supportive supervision of all health facility staff is crucial to achieve these advances.
2. Autoclaving would be an appropriate method for treating the waste, as the greatest proportion of waste is infectious in nature.
3. Develop recycling options for plastics and paper.
4. A centralized waste treatment plant is recommended, given the low quantities of waste generated at the lower-level facilities and the location of the region's health facilities. A location near Mbarara RRH would minimize the distance required to transport the bulk of the waste.
5. The minimum treatment plant capacity recommended is at least 60 kg/hour to handle the estimated expected quantity of waste from 13 districts for two shifts per day for six days each week.
6. Population growth in Mbarara District and larger-capacity technology should be considered.

8.0 SELECTION OF TECHNOLOGY FOR TREATMENT OF HEALTH CARE WASTE

8.1 Process of Technology Selection

Step 1: Define scope of problem, obtain baseline data, and consult stakeholders

Infectious HCW needs to be treated. Although baseline data for the waste generated from health facilities in Mbarara was not available, it was established that all waste collected from the hospital was being disposed in an open dumpsite away from the hospital, creating environmental, social, and health risks to the community.

Step 2: Strategic assessment to determine the best waste treatment approach

Given the findings of the study of Mbarara District health facilities, it is proposed that the facilities be served by a central treatment facility.

Justification of the centralized approach

More than 80 percent of the waste in the studied facilities was observed to be generated by Mbarara RRH, with limited quantities of waste generated by other facilities. First, such limited waste quantities do not justify having a treatment system at each health facility. Second, the use of a centralized system permits optimal utilization of available treatment technology and takes advantage of economies of scale. The location of the health facilities within the same geographical area also favors a centralized treatment system. In addition, the possibility of sharing costs could be economically advantageous.

Step 3: Facility-specific data obtained through a waste assessment

The waste assessment was conducted to obtain accurate data on waste generation rates to specify equipment capacity. The daily waste generation rate can be computed as follows:

kg/bed/day = total kg of waste in one day ÷ number of beds

Using the waste generation data and average bulk density, the total amount of waste requiring treatment per week was calculated in terms of kilograms and liters per week. The treatment capacity was then computed using two equations.

To figure capacity in kilograms per hour:

Facility HCW kg per week ÷ [(# of daily shifts) x (# of operating days per week) x 8]

To figure capacity in liters (volume) per day:

[kg of waste that can be handled per hour] ÷ [bulk density in kg/liter]

Weight of waste generated using total waste per week

Based on study findings, the weight of the waste generated across facilities in all 13 districts can be estimated as follows:

Table 14. Estimated Waste Quantities in 13 Districts Using Total Waste per Week

Facility Level	Kg Hazardous Waste per Week	# of Facilities Across 13 Districts	Total Kg Waste per Week
RRH	649.22	2	1,298.43
Ruharo General Hospital	54.95	13	714.35
HC IV	52.24	28	1,462.72
HC III	4.14	128	529.92
HC II	2.64	436	1,151.04
TOTAL			**5,156.46**

This analysis is only an estimate and does not take into consideration the waste generation rate per day, which is critical.

Option 1: Assuming the plant will work two eight-hour shifts each day and three days each week, *or* one shift per day for six days a week, the capacity in kilograms per hour would be:

$$= 5{,}156 \text{ kg/wk} \div (2 \times 8 \times 3)$$

$$= 5{,}156 \div 48$$

$$= 107.4 \text{ kg/hr}$$

Capacity in liters per day would be figured:

$$107.4 \text{kg/hr} \div 0.18 \text{ kg/liter} = 597 \text{ liters/day}$$

where 0.18 is the average bulk density for infectious waste.

Option 2: Assuming the plant will work two eight-hour shifts each day for six days a week:

$$5{,}156 \text{ kg/wk} \div (2 \times 8 \times 6) = 53.7 \text{ kg/hr}$$

$$= 53.7 \text{ kg/hr} \div 0.18 = 298 \text{ liters/day}$$

Quantity of waste generated using daily average waste generated

Based on study findings, the waste generated from the facilities in 13 districts can be calculated using the average waste generation rate per day (Table 15).

Table 15. Estimated Waste Quantities in 13 Districts Using the Average Waste Generation Rate per Day

Facility level	Kg hazardous waste per day	Number of beds	Percent bed occupancy per month	Waste generation rate [(kg/bed/day) ÷ (kg/patient/day)]	Average bed capacity	Kg waste generated per day	# of facilities at this level across 13 districts	Total kg waste generated across 13 districts per day	Total kg waste generated across 13 districts per week
RRH	92.7	451	0.74	0.28	500	138.88	2	277.76	1,944.33
Ruharo General Hospital	7.85	104	0.34	0.08	100	7.55	13	98.13	686.88
HC IV	7.46	46	0.46	0.16		7.46	28	208.88	1462.16
HC III	0.59	6	0.05	0.03		0.59	128	75.52	528.64
HC II	0.38	0	N/A	0.038		0.38	436	165.68	1,159.76
Total									**5,781.76**

For HCs II, III, and IV, the average number of outpatients per day was used as a basis for calculation.

Option 1: Assuming the plant will work two eight-hour shifts per day for three days a week, or one eight-hour shift a day for six days a week, the capacity in kilograms per hour will be:

= 5,781.76 kg/week ÷ (2 x 8 x 3)

= 5,781.76 ÷ 48 = 120.4 kg/hr.

Using the average bulk density for infectious waste, the capacity in liters is obtained:

= 120.4 ÷ 0.18 = 669.2 L/day

Option 2: Assuming the plant will work two eight-hour shifts per day for six days a week, the capacity in kilograms per hour will be:

= 5,781.76 kg/week ÷ (2 x 8x 6)

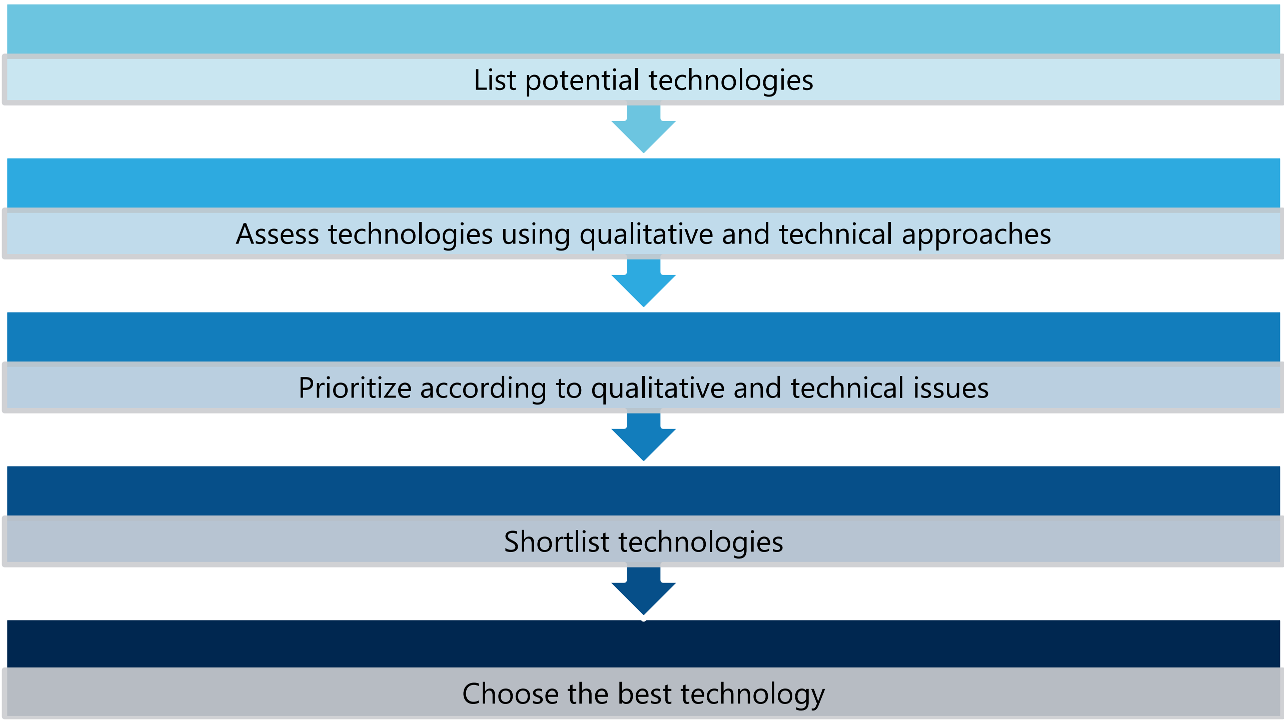
= 5,781.76 ÷ 96 = 60.2 kg/hr.

Using the average bulk density of infectious waste, the capacity in liters per day would be:

= 60.2 ÷ 0.18 = 334.5 L/day

Step 4: Screening process to eliminate generic technologies that do not meet basic criteria.

The chart below indicates the process of selection of the technology.



Factors considered in the screening process included:

Environmental and occupational safety

Incinerators, alkaline hydrolysis technologies, and chemical treatment systems were ruled out because they cause significant environmental and occupational safety concerns.

Social aspects and job creation potential

All technologies under consideration have potential to create jobs, and related social concerns are minimal.

Capital and operating costs

High capital costs ruled out:

- Hybrid waste treatment autoclave
- Continuous microwave unit
- Dry heat treatment systems
- Incinerator with air pollution control
- Alkaline hydrolysis
- Chemical treatment.

Institutional and regulatory requirements

No institutional or regulatory requirements ruled out any further technologies; institutional requirements are associated with most, and regulatory requirements are few.

Step 5: Scoping analysis to generate a short list of technologies

The above factors were used to generate a shortlist of potential technologies.

Step 6: Analysis to determine the best-suited technology

The technologies were subjected to technical and economic analysis to determine the best-suited technology.

8.2 Summary of Pros and Cons of Technologies for Developing Countries

A review of technical comparisons of treatment technologies considered a number of factors. Those reviewed included:

- Autoclaves
- Hybrid autoclaves
- Continuous steam treatment systems
- Batch microwave technologies
- Frictional heat treatment systems
- Dry heat treatment systems
- Incinerators
- Alkaline hydrolysis technologies
- Chemical treatment systems.

Technical comparisons were reviewed, and the following prioritized:

- Range of capacities
- Installation requirements
- Degree of automation.

A qualitative comparison of technologies was made, and the following criteria were prioritized:

- Environmental and occupational safety
- Capital costs
- Institutional and regulatory requirements.

These items were weighted, and the technologies under consideration scored against the criteria, as shown in Table 16.

Table 16. Weighting of Technology Selection Criteria

Criteria		Maximum points
1.	Minimal environmental and occupational safety concerns	10
2.	Lowest capital costs	10
3.	Minimal institutional and regulatory requirements	5
4.	Low degree of automation	10
5.	Minimal installation requirements	5
6.	Wide range of capacities	10
Total		**50**

The technologies were assessed as indicated in Table 17. Autoclaving ranked highest among the selected technologies. In view of the limited reduction in volume and no mass reduction, the autoclave is used with a shredder. The shredder reduces the volume of the waste significantly and makes the waste unrecognizable.

Based on the results of this assessment a combined system of an autoclave for waste treatment and a shredder for waste reduction—followed by landfilling the treated and reduced waste—would be most appropriate for HCW in Mbarara District.

Table 17. Assessment of Technologies Using Selected Criteria

Findings	Technology	Environmental and occupational safety (10)	Capital costs (10)	Institutional and regulatory requirements (5)	Low degree of automation (10)	Installation requirements (5)	Wide range of capacities (10)	Total score (50)	% score
1.	Autoclaves	3	8	5	10	3	10	39	78
2.	Hybrid autoclave	3	4	3	5	2	6	23	46
3.	Continuous steam	6	6	3	5	2	6	23	46
4.	Batch microwave	6	N/A	5	10	5	N/A	26	52
5.	Continuous microwave	6	4	3	5	2	6	26	52
6.	Frictional heat systems	6	2	3	5	2	3	21	42
7.	Dry heat treatment	6	4	5	10	5	0	30	60
8.	Incinerators with flu gas cleaning	0	2	2	5	0	6	15	30
9.	Alkaline hydrolysis technologies	2	6	3	5	2	3	21	42
10.	Chemical treatment systems	1	2	3	5	2	6	19	38

9.0 ANNEX: DATA TOOLS

9.1 Assessing Characteristics of Health Care Waste at Health Facilities in Mbarara District

Interview with Facility In-Charge

District..................................... Date.. ....

Name of Health Facility ....

Level of Health Facility ....Department ....Serial Number ....

Health Facility Ownership ....Service Delivery Area ....

Name of Facility In-Charge... ....

Years in Position ....Phone Number ....

S/N		Response/findings	Comments
1	GENERAL INFORMATION		
1.9	Average monthly OPD attendance (average for last complete 12 months)		
1.10	Average monthly inpatient attendance (average for last complete 12 months)		
1.11	Total bed capacity		
1.12	Average monthly bed occupancy in a period of year (for last complete 12 months)		
1.13	Average number of lab clients per month (average for last complete 12 months)		
2	HCW MANAGEMENT, INCLUDING EXPOSURE MANAGEMENT		
2.1	Is the HCW generated in this health facility segregated according to MOH color codes?	Yes No Don't know	
2.2	How much HCW (kg) in total is generated in one week?		
2.3	Of total waste generated in one week, how much of waste is:		
A	Sharps		

S/N		Response/findings	Comments
B	Infectious waste		
C	Highly infectious waste		
D	Pharmaceutical waste		
E	—Metallic waste		
F	—Plastic waste		
	—General waste		
2.4	Do you have a designated focal person for HCW management?	Yes No	
2.5	Do you have designated waste handlers at the facility?	Yes No	
2.6	How many?		
2.7	Are the waste handlers trained in HCW management?	Yes No	
2.7b	Describe the training (when, how long, who provided)		
2.8	Are all waste handlers fully vaccinated against hepatitis B (three doses of HBV)?	Yes No	
2.9	Have any of the waste handlers reported needlestick injuries in the last 6 months prior to today?	Yes No	
2.10	If yes, was postexposure management provided?	Yes No	
2.11	Is post-exposure prophylaxis (PEP) readily available at the health facility?	Yes No Don’t know	
2.12	If not, is PEP available within two hours through referral?	Yes No Don’t know	
2.13	Are waste handlers routinely provided with all required PPE: gumboots, heavy-duty gloves, overalls, apron, and mask?	Yes No Don’t know	
2.14	If not, what items are routinely provided?		

Interview with Stores Person

S/N		Response/findings	Comments
3	WASTE MINIMIZATION AND MANAGEMENT OF EXPIRIES		
3.1	What commodities for managing HCW–waste bins, liners, safety boxes—does this health facility routinely receive? Please list.		
3.2	When ordering items for use at the health facility, what do you do to ensure waste minimization?		
3.3	Over the last 12 months, have you had any items expiring while still in stock?	☐ Yes ☐ No ☐ Don't know	
3.4	If yes, what items expired while still in stock?		
3.5	How many kg of expiries did you have over the last 12 months?		
3.5b	What do you do with expiries?		
3.6	Do you know what materials the items brought to this store are made of (e.g., paper, plastics, metal)?		
3.7	Please name these materials:		
A			
B			
C			
D			
E			
F			
G			
H			
I			
3.8	Do you know how these materials are disposed of?	☐ Yes ☐ No ☐ Don't know	
3.9	How are the materials disposed of:		
	Paper		
	Plastic		
	Metal		
	Cotton/gauze		
	Glass		
	Other:		

Screening of Waste Handlers

S/N		Response/findings	Comments
4	HCWM PRACTICES AND SAFETY OF WASTE HANDLERS		
4.1	How long have you been working as a waste handler at this health facility?		
4.2	Have you ever been trained in HCW management?	☐ Yes ☐ No	
4.3	If yes, have you been trained in HCW management in the last two years?	☐ Yes ☐ No	
4.4	What topics did the training cover?		
4.5	Have you been vaccinated against hepatitis B?	☐ Yes ☐ No	
4.6	If yes, how many doses of hepatitis B vaccine did you receive?		
4.7	In the last six months, have you had any exposure to blood, bodily fluids, or needlestick injuries?	☐ Yes ☐ No	
4.8	What were you doing when you had the exposure?		
4.9	Did you report the exposure to your supervisor?	☐ Yes ☐ No	
4.10	Were you assessed for PEP?	☐ Yes ☐ No	
4.11	Was PEP given?	☐ Yes ☐ No	
4.12	Does the facility have a system for reporting exposures? Describe.	☐ Yes ☐ No ☐ Don't know	
4.13	Are you routinely provided with PPE?	☐ Yes ☐ No	
4.14	What PPE items are you routinely given?		
4.15	Do you use PPE at all times when handling HCW?		
4.16	If not, why not?		

Observation of Waste Segregation Practices

DISTRICT.. NAME OF HEALTH FACILITY.. ....

LEVEL OF HEATH FACILITY......DEPARTMENT.............................. ....SERIAL NUMBER ....

SERVICE DELIVERY AREA ....

DATE...NAMES OF OBSERVER AND SIGNATURE ....

Place an "X" in the box to document waste segregation observations made in service delivery areas.
N/A = not applicable (N/A)

SN		Observations				
		1. Yes	2. No	3. Not observed	4. N/A	Comments
1	Are color-coded waste bins available at service delivery point? Nonhazardous–black Infectious—yellow Highly infectious–red					
2	Does each waste bin have accompanying color-coded liner?					
3	Where injection is observed, is there a safety box for sharps waste disposal?					
4	When injection is observed, is the sharps waste being disposed of in the sharps container immediately after use?					
5	Where injection is provided, is the sharps container located within arm's reach of the provider?					
6	Is all other waste placed in the appropriate color-coded waste bin according to category of risk (as above)?					
7	Is there any effort to segregate waste?					
8	Is there a segregation chart in the area where waste is generated?					
9.	Which classes of HCW are being mixed together? (Please list)	a) b) c)				
9	Remarks:					

9.2 Health Care Waste Quantification—Moisture Content

DISTRICT.. NAME OF HEALTH FACILITY.. ....

LEVEL OF HEATH FACILITY ...... DEPARTMENT............................. .... SERIAL NUMBER ....

OWNERSHIP (PUBLIC/PRIVATE) .... SERVICE DELIVERY AREA ... .

DATE .... NAMES OF OBSERVER AND SIGNATURE ....

Place an "X" in the box to document waste segregation observations made in service delivery areas. N/A = not applicable (N/A)

	Responses	Comments
Service delivery area ***Specify OPD, lab, ward, clinic, theater, radiology, dental, etc.***		
Waste classification ***Sharps, infectious, highly infectious, pharmaceutical***		
Type of material ***Paper, plastic, cotton, tissue***		
Starting time ***Oven at 105^{O}C***		
Initial weight		
Weight of tray		
Duration ***Time in minutes***		

Time (Hours)	Weight (kg)	Time (Hours)	Weight (kg)
1		13	
2		14	
3		15	
4		16	
5		17	
6		18	
7		19	
8		20	
9		21	
10		22	
11		23	
12		24	

9.3 Health Care Waste Quantification—Determination of Calorific Value

DISTRICT.. NAME OF HEALTH FACILITY.. ....

LEVEL OF HEATH FACILITY...... DEPARTMENT.............................. .... SERIAL NUMBER ....

OWNERSHIP (PUBLIC/PRIVATE).. .... SERVICE DELIVERY AREA ... .

DATE ....NAMES OF OBSERVER AND SIGNATURE ....

	Response	Comments
Service delivery area *Specify OPD, lab, ward, clinic, theater, radiology, dental, etc.*		
Waste classification *Sharps, infectious, highly infectious, pharmaceutical*		
Type of material *Paper, plastic, cotton, tissue*		
Baseline temperature		
Dry weight/mass (g)		

Duration (Seconds)	Temperature (OC)	Duration (Seconds)	Temperature (OC)
1		13	
2		14	
3		15	
4		16	
5		17	
6		18	
7		19	
8		20	
9		21	
10		22	
11		23	
12		24	

9.4 Health Care Waste Quantification—Classification

DISTRICT.. NAME OF HEALTH FACILITY.. ....

LEVEL OF HEATH FACILITY ...... DEPARTMENT.............................. .... SERIAL NUMBER ....

OWNERSHIP (PUBLIC/PRIVATE) .... SERVICE DELIVERY AREA ... .

DATE .... NAMES OF DATA COLLECTOR AND SIGNATURE ....

S/N	Time	Service Delivery Point (e.g., OPD, lab)	Weight of waste by class (kg)							Comments
			Nonhazardous	Sharps	Infectious	Highly infectious	Pharmaceutical	Other	Total (kg)	

9.5 Health Care Waste Quantification—Physical Characteristics

DISTRICT.. NAME OF HEALTH FACILITY..

LEVEL OF HEATH FACILITY ......DEPARTMENT..SERIAL NUMBER ....

OWNERSHIP (PUBLIC/PRIVATE) ....SERVICE DELIVERY AREA ....

DATE...NAMES OF DATA COLLECTOR AND SIGNATURE ....

S/N	Time	Service Delivery Point (e.g., OPD, lab)	Weight of Material Composition (kg)									Comments
			Paper	Plastic	Metal	Needles and Syringes	Glass	Tissue	Cotton/Gauze	Other	Total (kg)	

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