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Solid waste characteristics and management strategies at ST Theresa (STT) and Holy Cross (HC) hospitals in Chirumanzu rural District, Zimbabwe

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Abstract

Management of solid waste from rural hospitals is among major problems affecting developing countries. This is mostly attributed to inadequate data related to quantity and quality of hospital solid waste. Similarly, information related to rural hospital solid waste characteristics and management is limited in Zimbabwe. However, SDGs complemented by Zimbabwe Vision 2030, NDS 1 advocates for sustainable solid waste management. Hence, enough data related to characteristics of solid waste from rural hospitals are required to attain sustainability. This research focuses on hospital solid waste characteristics and management strategies at STT and HC rural hospitals. Descriptive cross sectional research design which triangulates qualitative and quantitative paradigms was utilized. Interviews, observations, questionnaires were used to collect data. Quantitative data were analyzed using Statistical Package for Social Sciences whereas qualitative data were subjected to content analysis. Solid waste generated at STT encompasses non-hazardous (77.35%), hazardous waste (22.65%). At HC solid waste consists of non-hazardous (79%) and hazardous waste (21%). Respondents at STT (70.4%) and HC (72.7%) noted that solid waste was increasing. Solid waste was increasing due to various factors namely high use of disposable materials at HC (35.1%), STT (42.5%) and increase of patients at HC (30%) and STT (29.7%). Solid waste was indiscriminately stored in various types of containers although pedal operated bins and sharp containers were highly used at STT (72.4%) and HC (69.1%). Waste receptacles were transported to disposal sites using wheelbarrows and manual handling. Open pits and burning were among disposal strategies but incineration was regarded as the golden approach at STT (44.8%) and HC (41.8%). Inappropriate hospital solid waste management was due to shortage of finance at STT (38.1%) and HC (30.9%) and unawareness among health workers. Although it was worsened by lack of all stakeholder participation at STT (79.0%) and HC (76.4%). Consequently, the study recommended application of strategies which support circular economy, integrated approach, raising awareness of health workers and provision of enough resources to rural hospitals.

Keywords Rural hospitals, Hospital, Solid waste, Management strategies, Management challenges, ST Theresa (STT), Holy Cross (HC)

Introduction

Hospital solid waste refers to waste generated during diagnosis, medication, treatment and caring of patients with various health problems [5, 69]. Hospitals generate solid waste of different nature since patients with different ailments are served. Solid waste from hospitals includes hazardous and non-hazardous waste consisting

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of 15% and 85% respectively [42, 67]. A certain fraction of hospital waste is capable of causing more health risks to people and the environment. Although, a large proportion constitutes solid waste similar to general household domestic waste. Hazardous solid waste from hospitals includes pathological, infectious, toxic chemicals, radioactive, sharps, cytotoxic and pharmaceutical waste [10, 84]. Hazardous solid waste from hospitals is regarded as the 2nd most deleterious after nuclear and radioactive waste, as stipulated by 1989 Basel Convention (Annex et al. [106]). Non-hazardous hospital waste which is referred to as general waste include non-contaminated empty boxes, papers, plastics and food waste from the kitchen [20, 41]. General solid waste remains non-risk if not mixed with hazardous waste like pharmaceutical waste. Pharmaceutical waste includes contaminated and expired useless drugs or medicines, vials, serum and vaccines generated by hospitals [42, 59]. Pharmaceutical waste is generated in both urban and rural areas since location of hospitals and medicine use have no geographical boundaries.

Hospitals generate pathological waste including human tissues, organs and body parts [42] and disposed still fetuses as well as placentas [39]. Pathological waste also encompasses health and unhealthy body parts examined in laboratories by pathologists. Studies revealed that weight of detached body parts varies from a small number of grams to kilograms [42]. This implies that pathological waste adds a certain quantity of waste to solid waste generated at rural hospitals, particularly infectious waste. Sharp waste namely pipettes, nails, syringes, knives, scissors, needles, blades, infusion sets, razors and scalpels are generated at hospitals [41, 86], including at rural hospitals. Hospitals are sources of chemicals produced during patients' treatment procedures and cleaning [84, 85]. Generation of chemical waste from rural hospitals is inevitable since chemicals are highly used. Discarded hospital Personal Protective Equipment/Clothing (PPE/C) like aprons, boots, gloves, goggles and face shields are considered as infectious waste [84]; Wang et al. 2019). Infectious hospital solid is labeled as hazardous owing to its potential to cause diseases to people [68], Wang et al. 2019). Ali et al. [7] and Hossain et al. [36] concur that hospitals produce materials contaminated by radioactive substances and materials generated during vitro analysis and therapeutic procedures. Hospital radioactive waste contains radio nuclides with decomposing periods of hours to years [65]. Considering, hazardous waste from hospitals pinning of approaches which support circular economy is among difficult tasks.

General waste can be recycled or reused easily if efficient solid waste segregation is carried out at hospitals. This is less applicable since proper hospital solid waste management is still at miniature stage in developing nations not sparing the issue of segregation [19, 20]. Despite different physical characteristics hospital solid waste is managed together, making application of reuse difficult at rural hospitals. In developed countries such as Canada and the United Kingdom hospital solid waste is usually segregated and stored in recommended containers [5, 79]. As a result of proper waste separation processes like recycling, reuse and recovery are easily applied. Indiscriminate storage of hospital solid waste is common in developing countries such as Pakistan [5] and Zimbabwe [77, 78]. This scenario is worse at rural hospitals located in developing nations like India (Vitthal et al. [101]), Uganda [45], Malawi (Mmanga et al. [100]) and rural hospitals in Zimbabwe are not spared. Application of sophisticated strategies is difficult in Zimbabwe due to financial shortages, increase of waste, limited availability of data related to hospital solid waste quality and quantity [74–78]. The scenario is worse at rural hospitals since they receive little attention from policy makers and researchers. Management of hospital solid waste from rural hospitals usually follows a traditional linear approach which focuses on collection to disposal. Solid waste from rural hospitals is disposed into open pits, auto-way pits and through incineration, open burning, burying and open dumping [77, 78]. Most of the utilized strategies occupy the base of the waste management hierarchy hence can result in environmental problems.

Solid waste management strategies used at rural hospitals have potential to cause air, water, soil contamination while disturbing characteristics of existing vegetation. Human health is also at risk since health workers and waste scavengers are exposed to sharp waste injuries translating to occurrence of various infectious diseases including Hepatitis, Tuberculosis, HIV and AIDS. Inappropriate management of solid waste from rural hospitals has the potential to facilitate outbreak cholera, typhoid, dysentery, malaria since dumpsites serve as breeding sites for various vectors. This signifies little attention and knowledge related to rural hospital solid waste characteristics limiting ability to reach demands of Sustainable Development Goals (SDGs) in Zimbabwe. Although solid waste from rural hospitals presents environmental health problems little is known about the nature of solid waste generated and existing management techniques. Even the legal framework offers less attention to rural institutions encompassing rural hospitals. Urban Councils Act (Chapter 29:15) supports urban areas only (Jerie, [98]; [48] whilst the Rural District Councils Act (Chapter 29:13) is unclear about waste management in rural areas owing to the assumption that rural areas are spared by waste management problems. Nearly incapacitated rural hospitals shoulder the burden of managing

the increasing waste since waste services are skewed in favour of urban hospitals while neglecting rural hospitals. To worsen the scenario, studies related to aspects surrounding hospital solid waste characteristics are geographically confined since they focus much on urban hospitals as compared to rural hospitals. Issues surrounding understanding of solid waste characteristics and management from rural areas are still at an embryonic stage in Zimbabwe. This exposes rural environments which are generally less polluted at risk of being contaminated by poorly managed institutional waste. Therefore, the need to maintain the high environmental quality of the rural environment cannot be overemphasized.

To achieve sustainability in the realm of hospital solid waste management in rural areas of Zimbabwe, enough data are required. Therefore, this study puts emphasis on hospital solid waste characteristics and management strategies at rural hospitals in Chirumanzu district, Zimbabwe. The study was guided by specific objectives namely: (1) To characterize hospital solid waste generated by rural hospitals in Chirumanzu district. (2) To evaluate hospital solid waste management framework utilized by rural hospitals in Chirumanzu district. Results and recommendations of this study pave a route for proper management of hospital solid waste. This enabled the country to achieve SDGs namely good health and well-being, life on land, life below water and sustainable cities and communities among others. Understanding aspects surrounding hospital solid waste and management strategies speedy attainment of Zimbabwe National Development Strategy 1 (NDS 1) objective of environmental protection. Research findings facilitate collaboration of all responsible stakeholders in implementing policies which support proper management of solid waste from rural hospitals. Appreciation of the nature of solid waste and management strategies reduce difficulties in developing frameworks which support sustainable management of rural hospital solid waste.

Materials and methods

Description of the study area

The research was carried out in Chirumanzu rural district located in Midlands province, Zimbabwe. Chirumanzu occupies 4.737 square kilometres of Midlands province (Kori et al. [97]). The district is in agro-ecological zone 3, receiving average rainfall of 650 mm annually with average temperature between 24° and 30°C [56]. The district is mainly covered by sand-loam soil which supports vegetation species such as *Brachystegia specieforms l*ike Musasa [51], *Julbernadia globiflora* like Mutondo, and *Colospermun* (mopane) [52] and patches of grass (Fakarayi et al. [99]). People in the district practice subsistence farming. Moreover, population in the district grows at 1.2 percent per annum and its population is around 95 272 with 45 589 males, 49 683 females and 24.556 households [92]. Continuous growth of the population and need for health services add burden to hospitals since a large volume of solid waste is generated. Chirumanzu's population is served by clinics namely Nyautonge, Chizhou, Siyahokwe, Mhende, Doroguru, Hwata, Hama, Chimbindi and Chengwena. Rural hospitals in Chirumanzu district include ST Theresa, Holy Cross, Muvonde and Sanatorium. Nevertheless, the study focuses on ST Theresa (STT) (Fig. 1) and Holy Cross (HC) (Fig. 2) hospitals which are in wards 8 and 6, respectively. Total population of ward 8 is approximately 3 156 while ward 6 houses 3 478 people [92]. ST Theresa hospital was constructed in 1958 with bed capacity of 80 while Holy Cross hospital was constructed in 1960 with a bed capacity of 50. The two hospitals consist of different wards notably female, male, paediatric, maternity, isolation wards and departments such as administration, outpatient, family health clinic, laboratory, pharmacy, physiotherapy, doctors' offices and emergency rooms. This implies that a large number of people are served at these hospitals, therefore, generation of different types of solid waste in high quantities is inevitable. Holy Cross and ST Theresa hospitals were purposively selected since these hospitals also receive patients from health institutions in the primary level within the district and beyond. The hospitals are located in communal areas with high population density hence they serve a large proportion of people translating to generation of more solid waste.

Research methodology

Research design

Research design refers to a complete framework demonstrating how numerous techniques are used during research. Descriptive cross sectional research design that employs qualitative and quantitative paradigms was adopted in data collection, analysis and presentation.

Target population and sample size

The study targeted health workers namely nurses, doctors, physiotherapists, laboratory technicians, radiologic technologists, eye-opticians, cleaners and anesthetists at STT and HC hospitals as questionnaire respondents. Questionnaire survey targeted 147 and 64 health workers at STT and HC, respectively (Table 1). Sample size for questionnaire survey was determined using Taro Yamane [89] formula:

$$\mathbf{n} = \frac{N}{1 + N(e)^2}$$

Where:

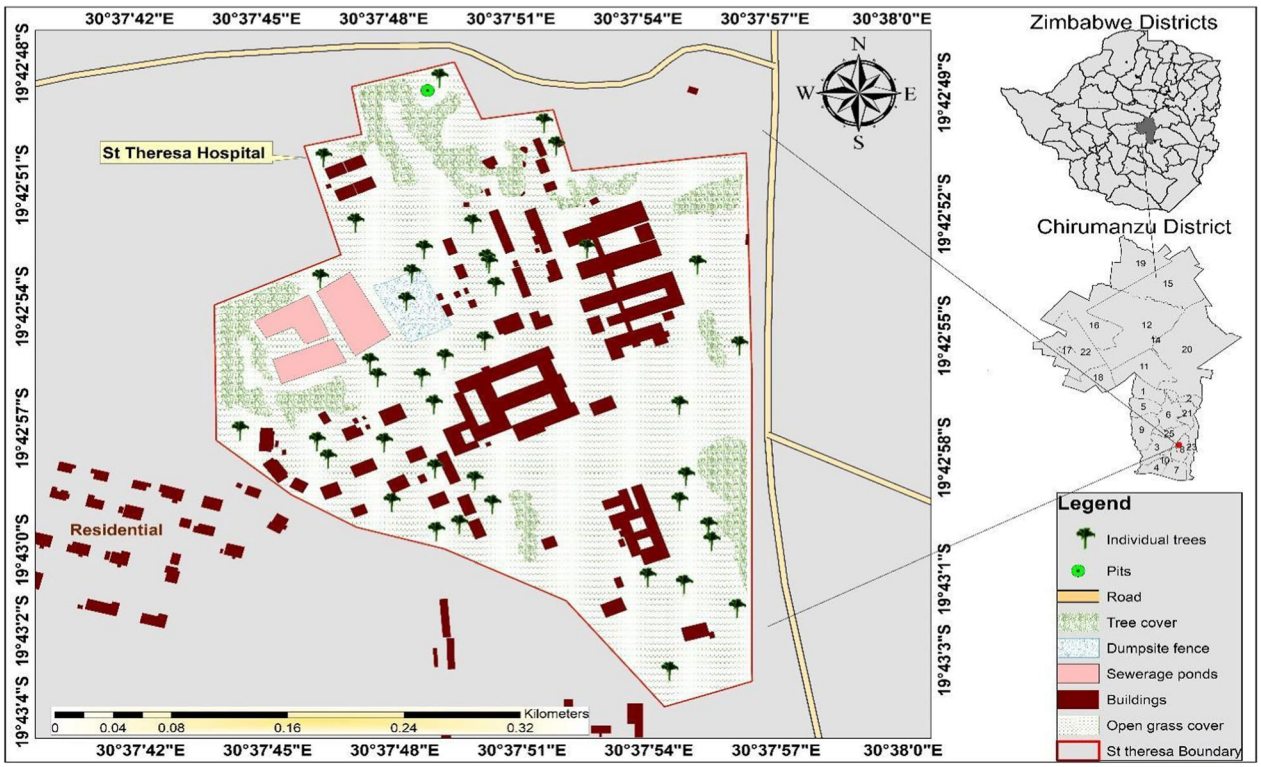

Fig. 1 Location and characteristics of ST Theresa hospital in Chirumanzu district. Source: Geographic Information System map derived from Google Earth image by the Author

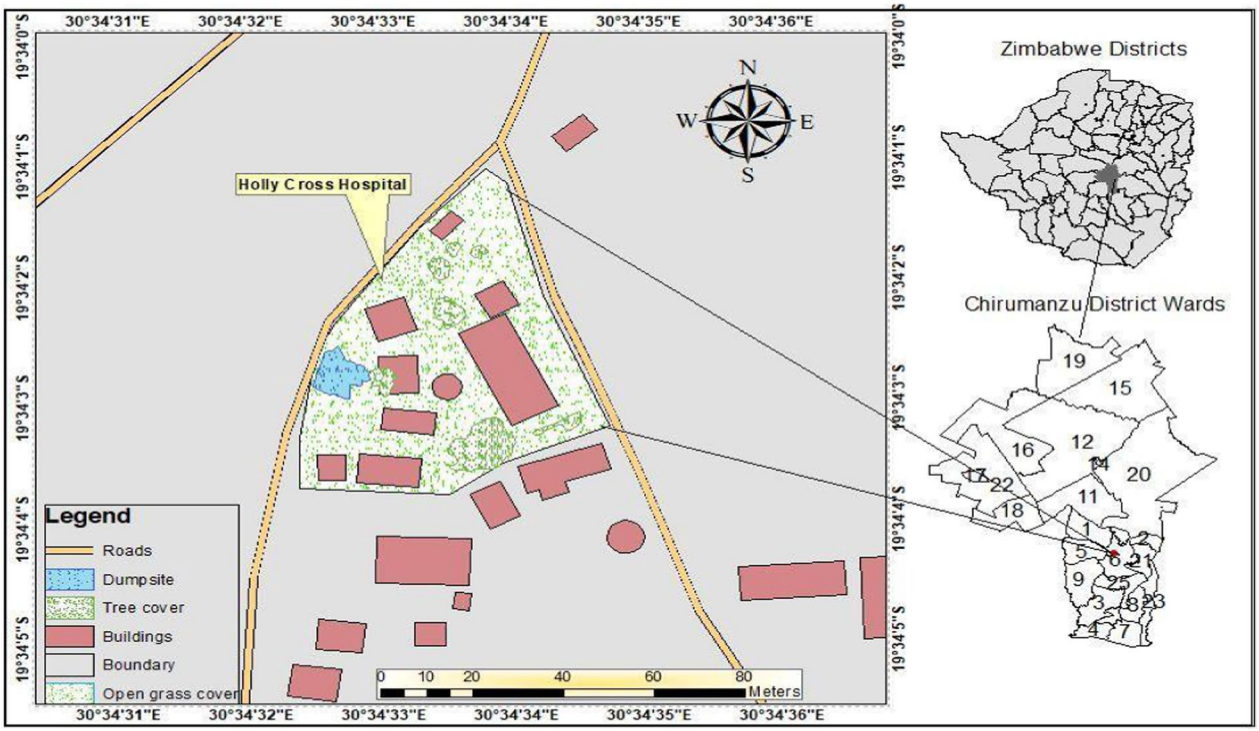

Fig. 2 Location and characteristics of Holy Cross hospital in Chirumanzu district. Source: Geographic Information System map derived from Google Earth image by the Author

Table 1 Sample size for questionnaire survey

Hospital name	Number of health workers	Grouping of workers according to their occupation	Required sample size using Taro Yamane formula n $= \frac{N}{1+N(e)^2}$	Sample size to represent each stratum $\frac{Required\ Sample\ Size}{Population\ size} \times strata\ size$	Total
ST Theresa	147	Nurses 118, Doctors 3, Laboratory technicians 4, Physiotherapist 2, Radiologic technologist 2, Anaesthetists 2, Eye optician 2, Cleaners 14	105	Nurses 86, Doctors 2, Laboratory technicians 3, Physiotherapist 1, Radiologic technologist 1, anaesthetists 1, Eye optician 1, Cleaners 10	105
Holy cross	64	Nurses 41, Doctors 1, Laboratory technicians 3, Physiotherapist 2, Radiologic technologist 2, anaesthetists 2, Eye opticians 1, Cleaners 12	55	Nurses 35, Doctors 1, Laboratory technicians 2, Physiotherapist 2, Radiologic technologist 2, anaesthetists 2, Eye opticians 1, Cleaners 10	55
		Total questionnaire respondents			160

Source: Authors

n = sample size.

N = total population.

e = margin of error 0.05 (± 5%).

After using Taro Yamane's formula, sample size was 105 at STT and 55 at HC hospitals (Table 1). After determining required sample size, stratified sampling procedure was applied to divide health workers into groups according to their occupation at hospitals (Table 1). Representatives of each stratum were proportionally determined following Bowley [16]'s formula: $\frac{Required\ Sample\ Size}{Population\ size} \times stratum\ size$. Questionnaire respondents from each stratum were selected using a simple random sampling method. Individuals for each stratum were numbered and a computer-generated random table was used to select strata representatives.

Targeted key informants were selected using a purposive sampling approach. Key informants include Chirumanzu District Medical Officer (DMO), Environmental Management Agency (EMA) Officer, hospital Environmental Health Technician (EHT), hospital Head of Cleaning Department/Supervisor (HCD/S) and Hospital Matron (HM).

Data collection methods

Questionnaires were used to solicit demographic data such as gender and level of education, since these can affect perceptions of an individual towards hospital solid waste management. Data regarding solid waste characteristics, management strategies and waste management challenges were collected through use of questionnaires. Interviews were conducted to collect data on the nature of hospital waste and management approaches. To validate data from questionnaires and interviews, observations were applied to collect data on hospital solid waste characteristics and management approaches. Already existing data on hospital solid waste and management techniques were retrieved from secondary sources.

Solid waste characterization and quantification

Characterization of hospital solid waste in different categories was done using WHO and UNICEF (2015) approach. Therefore, hospital solid waste was grouped into infectious, pathological, chemical, sharps, cytotoxic, pharmaceutical, radioactive and general solid waste. Different hospital solid waste types were loaded in labelled plastic bags (bin liners) with support of research assistants. During loading of solid waste in plastic bags segregation was carried through a hand sorting approach, since it is regarded as the accurate strategy to collect reliable data [33, 58]. Types of hospital solid waste under each category were recorded on solid waste characterisation form. Collection of data regarding quantity of hospital solid waste generated per patient and solid waste generated during days of data collection at each hospital was done. In terms of selecting a patient to deal with during the study specifically to obtain an average quantity of waste per patient per day, random sampling was applied. This was easy since hospital beds were numbered, therefore, a computer-generated random table was used to select the patient. Plastic bags or bin liners were given to selected patient. Data on the quantity of hospital solid waste generated were collected for 7 days. Determination of solid waste quantity and composition after 7 days present to minimize ambiguity since Jerie (2014) adopted it to collect accurate data during solid waste research. A digital weighing scale was used to weigh plastic bags to determine the weight of solid waste. Quantity of solid waste obtained during the weighing process was recorded in a notebook. Ahmed (1997)'s formula: Waste Generation Rate = Average Waste Production /Patient/day X Total Number of Patients admitted *(WGR = AWP/P/D X T No of P)*, was utilized to quantify solid waste generated by the hospital in relation to admitted patients per day.

Data analysis and presentation

Collected quantitative data were analyzed using Statistical Package for Social Sciences version 25.0 at 95 percent confidence level. Descriptive statistics such as mean, frequencies and mode were used to show response rate particularly for questionnaires. Analysis of hospital solid waste quantity average was carried out through descriptive analysis. Non-parametric tests like Chi-square was used to test association between association between number of admitted patients and quantity of hospital solid waste generated. Quantitative data were presented in the form of tables, charts and graphs. Qualitative data were analyzed through content analysis and presented using expressive and persuasive narratives as well as direct and indirect quotations.

Results and discussion

Socio-demographic data of healthcare workers

Majority of questionnaire respondents at STT and HC hospitals were females consisting of 62.9% and 56.4% respectively. This implies that female health workers dominate at these rural hospitals compared to male workers. This explains that culturally and socially females are interested in offering health services including caring for the sick. Females are in the forefront of offering health services to people with various ailments (Drennan and Ross, 2019; Murat et al. 2021). At STT hospital 29.5% of health workers are between 27 and 35 years, 13.3% (18–26 years) and 10.5% are 54 years and above. This was different to HC hospital where 30.9% of the health workers' age ranges from 36 to 44 years while 10.9% were between 18 and 26 years (Table 2). The hospitals include employees with significant work experience and those who are new in the health workforce. This causes variation in terms of knowledge, awareness and perspectives towards hospital solid waste management. A view supported by Woromogo et al. [86] and Akkajit et al. [6] that knowledge related to hospital waste management is determined by work experience.

In terms of educational level, 60% of the health workers at STT hospital are holders of diplomas and those with secondary level comprises 10.5%, although 3.8% have masters (Table 2). HC hospital accommodates 52.7% health workers with diplomas and 18.2% who attained secondary level. Dominance of diploma holders is attributed to the fact that most of the general nurses in Zimbabwe are holders of 3 year diplomas [28, 43]. Differences in level of education entail that a solid waste management framework which considers the level of knowledge of all health workers is required. Sustainable solid waste management framework must consider everyone [74–76] and people with different levels of knowledge are included. Only 15.2% of health workers at STT hospital have work experience of 12 years and above in comparison to 20% at HC hospital. Most of STT hospital's health workers' work experience was 0 to 5 years, yet at HC hospital it was 6 to 11 years (Table 2). At STT 31.4% of health workers have work experience of 6–11 years. This potentially affects

Table 2 Socio-demographic data of healthcare workers at ST Theresa and Holy Cross hospitals

Variable	Response category	Respondents at each hospital					
		ST Theresa Hospital			Holy Cross Hospital		
		Frequency	%	Cumulative %	Frequency	%	Cumulative %
Gender	Males	39	37.1	37.1	24	43.6	43.6
	Females	66	62.9	100.0	31	56.4	100
Age	18–26	14	13.3	13.3	6	10.9	10.9
	27–35	31	29.5	42.8	12	21.8	32.7
	36–44	23	21.9	64.7	17	30.9	63.6
	45–53	26	24.8	89.5	11	20.0	83.6
	54^{+}	11	10.5	100.0	9	16.4	100.0
Educational level	Secondary	11	10.5	10.5	10	18.2	18.2
	Certificate	20	19.0	29.5	13	23.6	41.8
	Diploma	63	60.0	89.5	29	52.7	94.5
	Degree	7	6.7	96.2	3	5.5	100
	Masters	4	3.8	100.0	0	0	
Work experience (years)	0–5	56	53.3	53.3	13	23.6	23.6
	6–11	33	31.4	84.8	31	56.4	80.0
	12^{+}	16	15.2	100.0	11	20.0	100.0

Source: Field data (2023)

$^{+}$ represnt 54 years and above as well as 12 years and above

hospital solid waste management, since generally workers with more work experience have better understanding owing to participation in various workshops and training. This concurs with [77, 78] that more experienced health workers have better knowledge about waste management and associated environmental health risks. At STT hospital 13.3% of the respondents were in the maternity department and 12.4% in the paediatric ward (Table 3). This was slightly different to Holy Cross where the paediatric ward was served by 10.9% of the health workers. More health workers were found in the maternity department because it consists of various sections and activities while caring for young children in the paediatric ward is demanding.

Characteristics of hospital solid waste generated at ST Theresa and Holy Cross hospitals

In terms of the nature of hospital solid waste generated at these two hospitals, data collected from questionnaires and observations concur. Broad categories of hospital solid waste produced were pharmaceutical, sharps, infectious, pathological, cytotoxic, radioactive, chemical and general solid waste (Table 4). This indicated that solid waste generated at STT and HC hospitals consist of hazardous and non-hazardous waste. Similarly, rural healthcare facilities in Vhembe district in Limpopo province, South Africa [62]. STT EHT further grouped hospital solid waste into combustible and non-combustible waste. Non-combustible solid waste highlighted include food leftovers, glass and metals while combustible solid waste encompass papers, plastics, gloves, textiles, cotton wool, empty boxes. As a result, a certain proportion of hospital solid waste can go through the energy recovery process. Observations indicated that hospitals are sources of construction and demolition waste namely broken bricks and tiles. Renovation, maintenance and expansion of hospital structures generate construction and demolition waste [8, 32]. Electronic waste encompasses disposed cartridges, sphygmomanometer, printers, computers and pieces of electric cables. This implies that technological evolving was among drivers of solid waste increase at these rural hospitals. This suggests that Zimbabwean health institutions are sources of electronic waste (Jerie and Shabani, [95]). Cleaning supervisor at STT hospital highlighted that textile waste such as pieces of cloth are generated from the sewing and laundry department. At HC hospital, the EHT and Matron concur that solid waste produced encompass organic waste such as food and pathological waste and inorganic solid waste namely sharps, textiles, gloves, aprons, papers, plastics and theater caps. As a result, solid waste from rural hospitals comprises biodegradable and non-degradable waste. A view upheld by Ghimire and Dhungana [30] that hospital solid waste consists of non-degradable and degradable waste.

Table 3 Categories of questionnaire respondents according to the department they were attached to during the survey

Department	Respondents at each hospital					
	ST Theresa Hospital			Holy Cross Hospital		
	Frequency	%	Cumulative %	Frequency	%	Cumulative %
Pediatric ward	13	12.4	12.4	6	10.9	10.9
Eye Unit	3	2.9	15.2	2	3.6	14.5
Family Health Clinic	6	5.7	21.0	4	7.3	21.8
Female Ward	9	8.6	29.5	4	7.3	29.1
Male Ward	9	8.6	38.1	4	7.3	36.4
Maternity Ward	14	13.3	51.4	5	9.1	45.5
Outpatient Department	11	10.5	61.9	4	7.3	52.8
Hospital Laboratory	4	3.8	65.7	2	3.6	56.4
X-ray Department	3	2.9	68.6	1	1.8	58.2
Theatre section	9	8.6	77.2	5	9.1	67.3
Rehabilitation Department	2	1.9	79.1	2	3.6	70.9
Isolation Wards	9	8.6	87.7	4	7.3	78.2
Doctors Rooms	2	1.9	89.6	1	1.8	80
Cleaning Department	10	9.5	99.1	10	18.2	98.2
Anesthetist Rooms	1	1.0	100	1	1.8	100

Source: Field data (2023)

Table 4 Hospital solid waste generated at ST Theresa and Holy Cross hospitals

Types of solid waste generated	Components of the solid waste
Pharmaceutical	Outdated/expired drugs, soiled drugs (tablets), remains of drugs, defective tablets, empty containers and sachets of drugs/medicine
Sharps	Iron/steel nails, surgical knives, hypodermic needles, syringes with needles, broken glasses, infusion tubes or sets, blades, slides, pipettes and metal scrap
Infectious	Culture/specimen containers, contaminated (cotton wool, gauze, mattresses, cotton swabs, plaster caster and bed linen), soiled gloves, towels, masks, gowns, bandages, diapers, pads and theatre caps
Pathological	Severed limbs, health and unhealthy tissues, body parts and organs
Cytotoxic	Remains of cytotoxic drugs, materials contaminated by materials used to suppress cell growth and cancer
Radioactive	Unsealed radionuclides, materials contaminated by radioactive materials and absorbent paper
Chemical	Containers of chemicals such as reagents, disinfectants
General	Food waste (sadza, vegetables, maize cobs and fruits), stationary (files, papers, book covers), water and drink bottles, package materials (empty boxes, plastics)

Source: Field data (2023)

Generation trend and quantity of hospital solid waste

Respondents at STT hospital (53.3%) agreed that solid waste was increasing while 17.1% strongly agree (Fig. 3). At HC hospital 50.9% agreed whilst 21.8 strongly agreed that solid waste was increasing. The DMO postulated that comparing the rate of hospital solid waste generation with the previous years, there was a slight increase. Hospital solid waste is increasing at both rural and urban hospitals in developing and developed countries [10, 41]. Although, respondents at STT (10.5%) and HC (10.9%) were not sure if hospitals are increasing or not (Fig. 3). This contradicts with the EMA Officer who noted that the solid waste increase at these rural hospitals was overwhelming the capacity of rural hospitals. Research findings demonstrated that 31.1% of health workers at STT and 32.5% at HC hospital pointed out that solid waste was increasing at a high rate. Therefore, it is clear that the quantity of hospital solid waste was exceeding the threshold of previous years. Increase of solid waste adds burden to already struggling rural hospitals [45, 70, 70].

In terms of drivers of solid waste increase, 42.5% of the respondents at STT hospital and 35.1% at HC hospital (Fig. 4) highlighted high use of disposable PPE/C. Questionnaire respondents, DMO and Matrons revealed high use of disposable gloves, masks, theatre caps and aprons to curb spread of infectious diseases. High utilization and compulsory use of PPE/C among health workers accelerates generation of solid waste [31, 81]. In total, 30% of health workers at HC, 29.7% at STT hospital and EHT pointed that increase of solid waste was attributed to the large number of patients offered services. Solid waste increase was owed to population proliferation in the catchment area since those people seek assistance from these hospitals, although people from other districts are among the patients. According to [77, 78] if the number of patients offered services at any hospital rises, solid waste also increases.

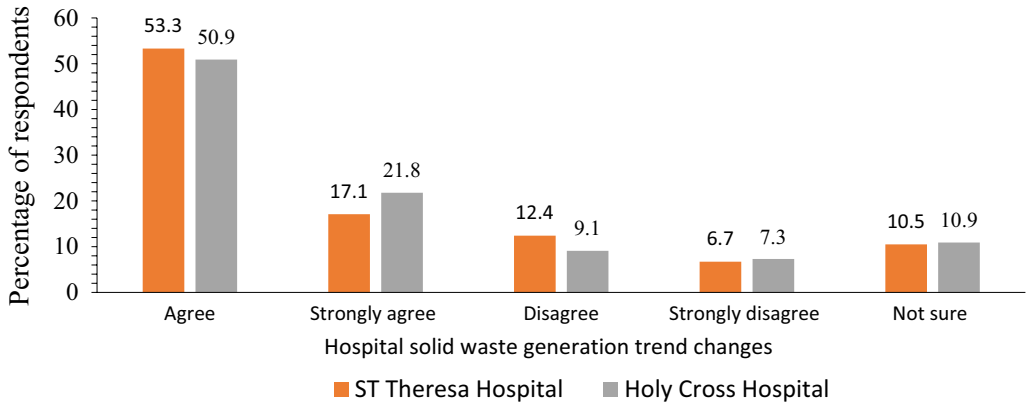

Fig. 3 Questionnaire respondents' perceptions on hospital solid waste generation trend changes Source: Field data (2023)

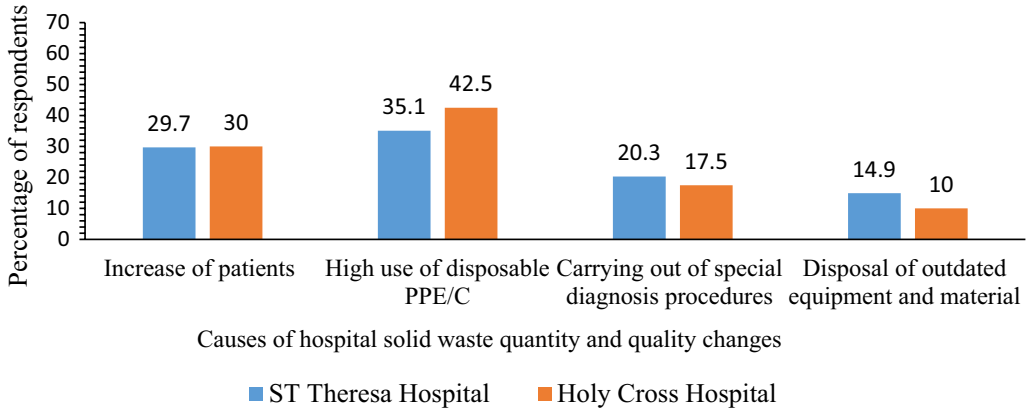

Fig. 4 Causes of hospital solid waste quantity and quality changes. Source: Field data (2023)

Results suggest that 20.3% respondents at STT hospital expressed the issue of carrying out special diagnosis procedures among causes of hospital solid waste increase (Fig. 4). Health workers postulate that procedures such as Full Blood Count (FBC), minor and major operations produce various types of sharps and infectious waste since a number of items are utilized. The proportion of questionnaire respondents who mentioned disposal of outdated equipment and material as one of the key aspects causing solid waste increase was 10% at HC and 14.9% at STT (Fig. 4). Respondents articulated equipment such as non-functioning clinical thermometers, weighing scales, sphygmomanometer, electrical lamps, printers, cartridges, pharmaceuticals and computers.

At HC hospital, average solid waste generated per patient per day was 0.83 kg. This was used to calculate solid waste generated at HC hospital per day (Table 5). Quantity of solid waste generated at Holy Cross depends on the number of inpatients (Table 5). Average quantity of solid waste generated per patient per day at HC is supported by Khudhair [44]'s in Iran which shows that 0.83 kg of waste was generated per patient per day. At STT hospital, the quantity of solid waste produced per patient per day was 0.87 kg and this was utilized to calculate the quantity of solid waste generated per day at the hospital (Table 5). Findings at each hospital revealed that the number of patients influenced the quantity of solid waste generated. This concurs with Ansari et al. [10] and Sangkham, (2020) that total number of patients served

Table 5 Quantity of hospital solid waste produced in relation to number of admitted patients

Hospital Name	Days when data was collected	Number of admitted patients per day of data collection	Quantity of waste generated per day (Kg) per each day of data collection
Holy Cross	1	46	38.18
	2	41	34.03
	3	36	29.88
	4	43	35.69
	5	33	27.39
	6	38	31.54
	7	29	24.07
ST Theresa	1	91	79.17
	2	88	76.56
	3	68	59.16
	4	77	66.99
	5	83	72.21
	6	61	53.07
	7	54	48.72

Source: Field data (2023)

Table 6 Chi-Square Tests of solid waste generated at ST Theresa hospital and number of patients

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	168.000[a]	36	0.000
Likelihood ratio	101.311	36	0.000
Linear-by-linear association	26.928	1	0.000
N of valid cases	28		

[a] 49 cells (100.0%) have expected count less than 5. The minimum expected count is .04

Source: Field data (2023)

Table 7 Chi-Square Tests of solid waste generated at Holy Cross hospital and number of patients

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	168.000[a]	42	0.000
Likelihood ratio	101.311	42	0.000
Linear-by-linear association	26.984	1	0.000
N of valid cases	28		

[a] 56 cells (100.0%) have expected count less than 5. The minimum expected count is 0.04

Source: Field data (2023)

at a health facility affect the quantity of solid produced directly. Admission and discharge of patients explains the fluctuation of patient numbers and quantity of solid waste (Table 5). HC hospital generated a maximum of 38.18 kg, a minimum of 24.07 kg and an average of 31.54 kg of solid waste during data collection days. However, STT hospital produced a maximum of 79.17 kg, 48.72 kg minimum and an average of 65.13 kg during the data collection period. This illustrates that although these hospitals are in the same district, but waste generation rate differs. A scenario which can be better explained by variation in terms of services offered and number of patients served at each hospital.

Pearson Chi-square test conducted on data collected from ST Theresa (Table 6) and Holy Cross (Table 7) hospitals, demonstrated a value of 0.000, which is less than the significance level of 0.05. Therefore, Pearson Chi-square tests demonstrated that there was association between the quantity of solid waste generated and number of patients at these hospitals. The results are in line with studies carried out in Zimbabwe by [77, 78].

Average composition of hospital solid waste generated at STT hospital was dominated by general waste (77.35%), 9% infectious, Chemical waste (2.3%), pharmaceutical (2.35%) and 3.88% sharp waste (Fig. 5). Composition of cytotoxic waste was 0.15% and radioactive waste (0.77%) and 4.2% pathological waste at STT hospital. Composition of waste produced at STT hospital shows existence of solid waste with similar characteristics to general domestic waste in large volumes. However, if waste is improperly segregated, the whole proportion of the waste becomes hazardous [77, 78], Shabani et al. [96]. A significant composition of general waste (79%) was generated at Holy Cross hospital with 7.59% infectious waste (Fig. 6). Average composition of chemical waste was 2%, 5% pathological waste and 3% pharmaceutical waste at Holy Cross hospital. A small percentage of solid waste consists of radioactive waste (0.71%) and cytotoxic waste (0.5%)

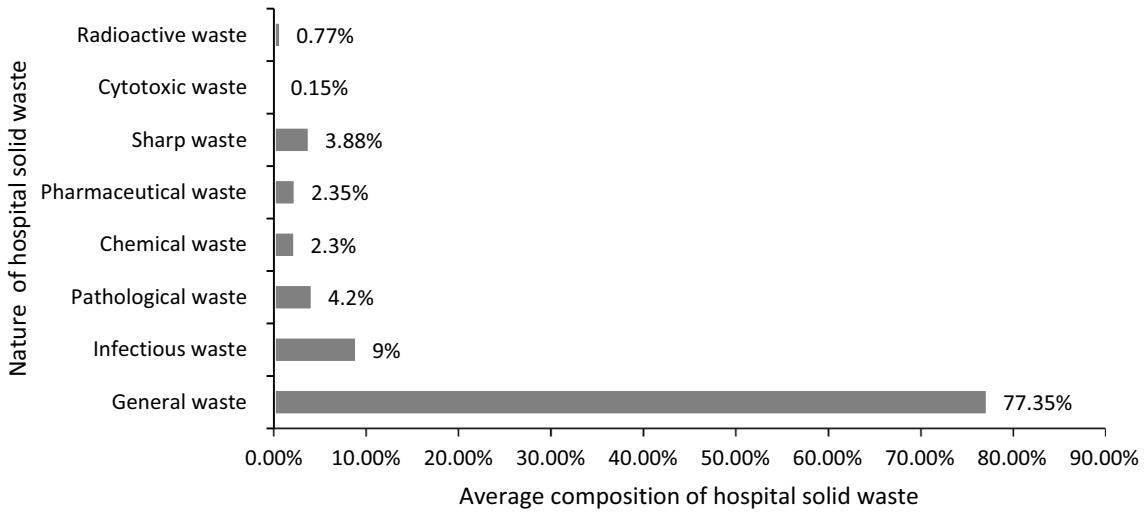

Fig. 5 Average composition of hospital solid waste generated at ST Theresa hospital per week (percentage by weight) Source: Field data (2023)

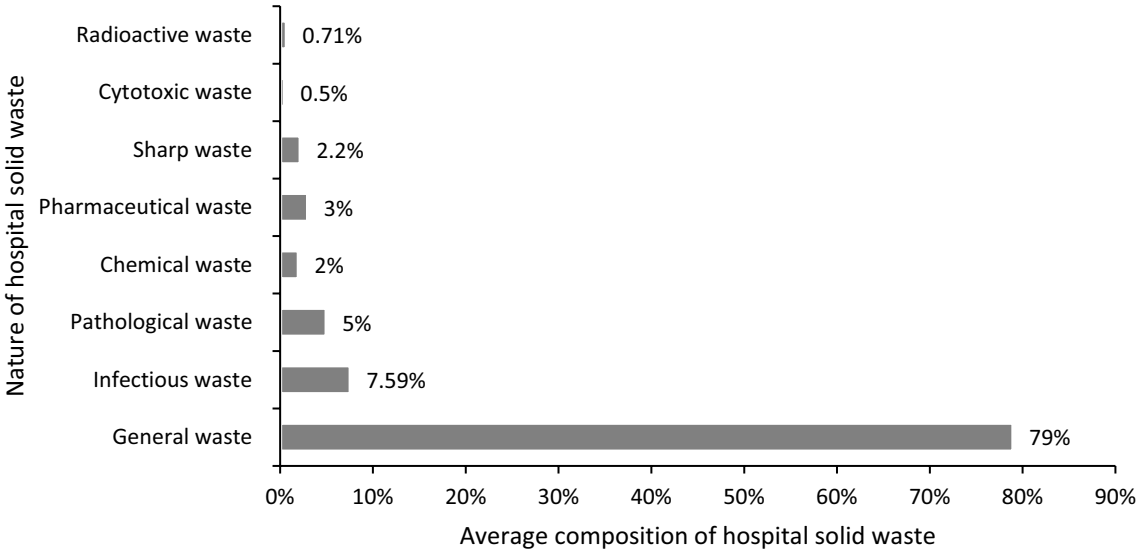

Fig. 6 Average composition of hospital solid waste generated at Holy Cross hospital per week (percentage by weight) Source: Field data (2023)

and sharp waste (2.2%) at Holy Cross hospital. Considering the composition of solid waste (Figs. 5, 6), it is clear that the large quantity of generated waste was non-hazardous and a minor proportion was hazardous. Findings are almost similar to Behnam et al. (2020) and Agamuthu and Barasarathi, [105]'s studies that approximately 75 to 80% of hospital solid waste is non-hazardous while 20 to 25% is hazardous.

Hospital solid waste management approaches at ST Theresa and Holy Cross hospitals

Types of hospital solid waste storage receptacles used at the two hospitals

Different hospital solid waste storage receptacles were identified among them include sharp containers, metal buckets and pedal operated bins (Fig. 7). This was supported by respondents at STT hospital (72.4%) (Fig. 8) and EHTs who mentioned sharp containers, foot operated bins and plastic bags. A total of 6.7%, 16.2% and

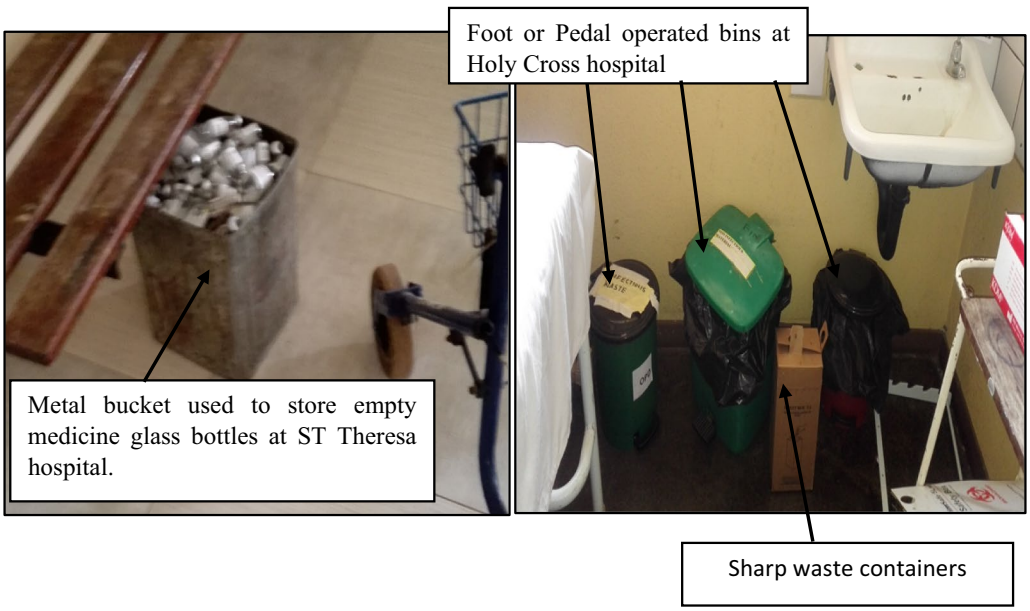

Fig. 7 Hospital solid waste storage receptacles Source: Field data (2023)

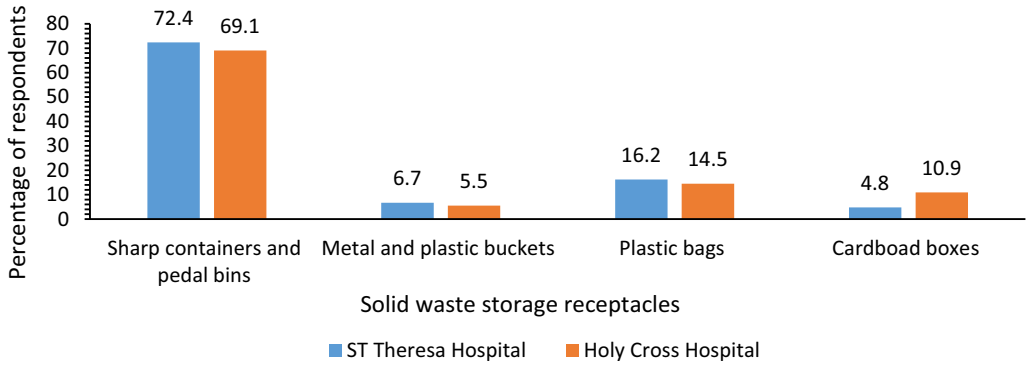

Fig. 8 Types of hospital solid waste storage receptacles used Source: Field data (2023)

4.8% respondents at STT hospital indicated metal and plastic buckets, plastic bags and cardboard boxes, respectively, as storage containers. Different types of solid waste receptacles are also used at hospitals in India [80] and in Nigeria [4]. At HC hospital 16.2% highlighted plastic bags while 5.5% mentioned metal and plastic buckets whereas utilization of sharp containers and pedal operated bins was confirmed by 69.1% (Fig. 8). Popularity of sharp containers was probably attributed to its characteristics among them include being made of puncture resistant materials. Sharp containers are mostly used at hospitals because they are leak proof, puncture proof and are recommended by WHO [60, 87]. Pedal operated bins are highly used as storage containers at the hospitals under study (Fig. 8). Dominance of pedal operated bins at hospitals is attributed to its hygienic nature since the bins are opened without using hands [77, 78]. Observations indicated that large waste containers with potential to accommodate 50 kgs of waste are placed at open spaces and inside building at STT hospital (Fig. 9).

Regarding hospital solid waste segregation, observations suggest that storage containers were labelled as infectious and non-infectious waste bins (Fig. 10) while some were penciled plastics and papers (Fig. 11). Despite the existence of labelled bins, contaminated and non-contaminated materials were found in one container. This illustrates that conformity of health workers to labels on the bins was low, denoting lack of awareness as well as negative attitude to proper waste segregation. At STT and HC it was observed and supported by EHTs that solid waste was separated into sharps and non-sharps during storage. This was supported by questionnaire respondents at STT (41%) and HC (32.7%) hospitals (Fig. 12). A view upheld by Ansari et al. [10] that sharp waste and non-sharps must be stored in separate containers. However, at STT and HC existence of sharps including razor blades, needles and slides was observed in bins with soiled linen and disposable towels. However, respondents at HC hospital (67.3%) and STT (35.2%) argued that infectious and non-infectious waste was stored in different containers. Separation of hospital solid waste into infectious and non-infectious waste is common at various medical facilities across the globe [23, 34]. According to the STT hospital cleaning supervisor, contaminated and non-contaminated solid waste was stored in different receptacles. Observations revealed that food

Fig. 9 Large metal **A** and plastic bins **B** used to store solid waste at ST Theresa hospital. Source: Field data (plate 2023)

Fig. 10 Solid waste receptacles for infectious waste, non-infectious materials and sharps at Holy Cross hospital. Source: Field data (2023)

Fig. 11 Receptacles for plastic and paper waste at ST Theresa hospital Source: Field data (2023)

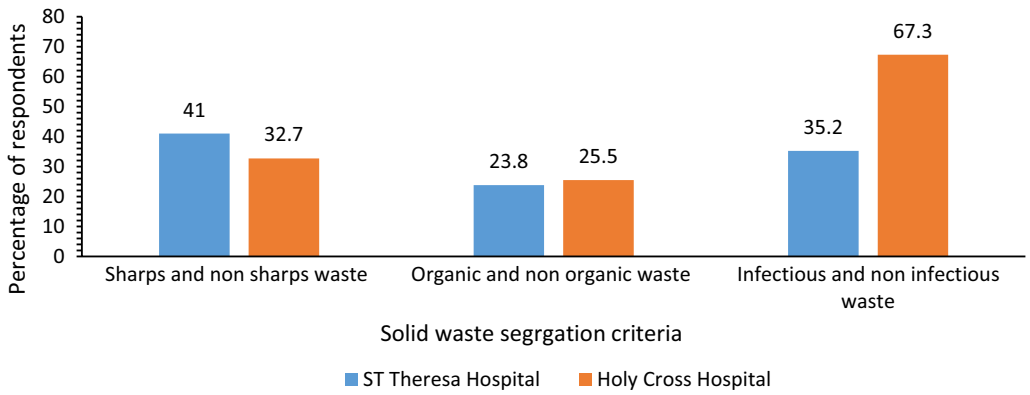

Fig. 12 Hospital solid waste segregation during storage Source: Field data (2023)

waste, empty plastics, papers and other contaminated materials were stored in the same receptacles in certain wards and rooms at these hospitals. This means indiscriminate storage of solid waste also exists at these rural hospitals, however, this increases difficulties in management of solid waste. Mismanagement of solid waste is worsened by co-storage waste at both urban and rural hospitals [74–76].

The EHTs at STT and HC hospitals denote that solid waste separation status at their hospitals was according to standards. The EHTs were highlighting their efforts to separate sharps and non-sharps and infectious and non-infectious waste. This concurs with respondents at STT (31.4%) and HC (32.7%) who claim that hospital solid waste segregation standard was good and a total of 39.0% respondents at STT hospital who indicated very good (Fig. 13). This contradicts observations since plastics, sharps and papers were noticed in the same bins in some hospital wards. Consequently, the solid waste segregation system at STT and HC fails to adequately address demands of WHO and Zimbabwe Ministry of Health and Child Care. This concurs with [20] that in developing nations the standard of hospital solid waste segregation is far-off from sustainability. A minor proportion of health workers at HC (10.9%) and STT hospitals (7.6%) considered segregation at the storage stage as poor (Fig. 13). The EMA Officer argued that evidence of improper segregation at the storage stage was illustrated by mixed waste at disposal sites. This entails that the appearance of plastics, food waste, bottles and papers in the same spits was a tail end issue of improper segregation during storage. This is supported by Angmo and Shah [9] and Pujara et al. [66] that existence of non-segregated waste at disposal sites demonstrates evidence of indiscriminate storage of solid waste.

Treatment of solid waste at Holy Cross and ST Theresa hospitals

Highly infectious solid waste from various hospital departments was disinfected through chlorination and autoclaving. EHTs and the DMO indicated that to destroy bacteria, fungi and viruses, infectious materials are exposed to steaming, high temperature and pressure in an autoclave machine. Chlorination and autoclaving is usually used to treat solid waste expected to contain infectious organisms in less developed countries [10, 19] and Zimbabwe is not exempted. The DMO supported by EHTs from both hospitals revealed that an oxidizing agent named chlorine was used to eradicate microorganisms on contaminated materials. The DMO said, *"Chlorination is capable of destroying various microorganisms, although it is not suitable to treat hospital radioactive waste".* This goes in line with Ahmad et al. [5] and Chisholm et al. [19]'s studies that chlorination has the potential to destroy pathogens. This entails that chlorination has the potential to destroy viruses and bacteria, thus suppressing spread of diseases associated with infectious waste. Adequate efficiency of chlorination was hindered by non-segregation of solid waste at various stages of management. However, results indicated that solid waste from these rural hospitals was usually transported to disposal sites without receiving proper treatment due to shortage of resources. Shortage of resources is also experienced at rural hospitals in Uganda [45].

Transportation of solid waste at Holy Cross and ST Theresa hospitals

Observations and EHTs revealed that health workers transported hospital solid waste to disposal sites manually. Manual handling of hospital solid waste receptacles facilitates removal of waste from the generation site, although it exposes health workers to back, hand and shoulder pain. Manual handling of solid waste receptacles results in musculoskeletal disorders [18]. Sharp containers and large bins were transported to the incineration site using wheelbarrows. Questionnaire respondents at hospitals under study indicated use of wheelbarrows and manual handling of waste receptacles. They argued that manual handling of solid waste receptacles to disposal sites was attributed to limited resources, specifically finance. Most rural hospitals in developing countries are operated without adequate resources

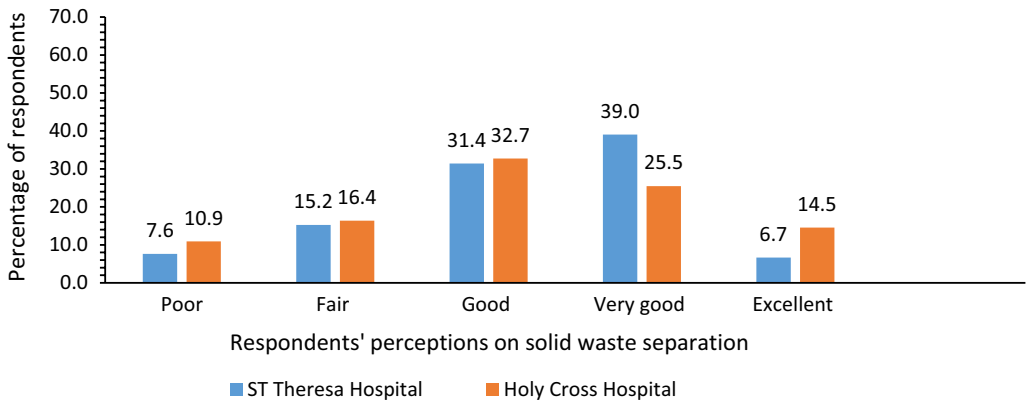

Fig. 13 Questionnaire respondents' perceptions on standard of hospital solid waste separation. Source: Field data (2023)

(Manyisa and van-Aswegen, 2017 [19]). At STT and HC hospitals, multipurpose trolleys were used to deliver waste containers to rooms where waste was treated. This suggests that rural hospitals require support in form of finance to purchase trolleys which are specifically for waste transportation.

Frequency of emptying hospital solid waste receptacles

Results of the study at STT hospital (87%) and HC hospital (78%) depict that solid waste receptacles were emptied on a daily basis (Fig. 14). This coincides with views of hospital Matrons and Cleaning supervisors at these hospitals. Daily conveyance of solid waste receptacles is significant since it reduces spread of waste related diseases among patients and health workers. In addition, emptying of waste containers on a daily basis is a requirement by WHO guidelines. Data gathered during observations highlighted that stored solid waste was generating noxious odours and molds in storage receptacles. This means solid waste was allowed to remain in storage containers for more than two days as highlighted by respondents at STT (10%) and 15% at HC hospitals. This signifies that frequency of emptying waste receptacles sometimes contradicts WHO and ZMoHCC waste management guidelines. Solid waste management activities encompassing emptying of storage receptacles at health institutions is usually less sustainable [7]. A total of 3% and 7% participants at STT and HC hospitals, respectively, indicated that waste storage containers were emptied twice a day (Fig. 14). This small proportion points out that emptying of solid waste receptacles twice a day was rare. Hospitals' EHTs, Cleaning supervisors and DMO concur that hospital sharp waste was disposed when the container was ¾ full. Disposal of containers with sharp waste was not determined by number of days but quantity in the container. Similarly, sharp waste containers are disposed when they are ¾ full at hospitals in South Africa [55].

Disposal of solid waste at Holy Cross and ST Theresa hospitals

Disposal of hospital solid waste was carried out within hospital yards as observed at STT and HC hospitals. Field observations illustrated that hospital solid waste produced at STT and HC hospitals was disposed into open pits, incinerators, auto-way pits and open burning. The findings are similar to studies carried out in Niger state in Nigeria by [2]. A view also revealed by Awodele et al. [12] and Chisholm et al. [19] that a number of approaches are used to dispose waste at medical facilities in African nations including Zimbabwe. An incinerator was used to dispose various types of solid waste at HC (Fig. 15) and at STT hospital (Fig. 16). Incineration was highly used as alluded to by respondents at STT hospital (44.8%) and HC hospital (41.8%) (Fig. 17). Incineration was used to dispose various types of solid waste namely papers, plastics, infectious waste like soiled masks, gloves, bandages, cotton wool and textiles as well as pharmaceutical waste. The issue of sharp waste incineration was supported by Cleaning supervisors and EHTs at the hospitals under study. Results of the study concur with findings obtained at Mwananyamala and Temeke regional referral hospitals in Tanzania [35, 71]. Incineration is highly utilized to dispose hospital solid waste because it reduces volume and toxicity of hazardous waste from hospitals [7, 10]. Moreover, observations revealed that auto-way pits were used to dispose hospital solid waste at HC hospital (Fig. 18) and STT hospital (Fig. 19). Pathological waste namely body parts and organs are discarded in auto-way pits as alluded by respondents at STT (27.6%) and HC (29.1%) hospitals (Fig. 17). This is in line with [77, 78] that pathological waste from health institutions is disposed in auto-way pits.

Hospital solid waste was disposed through open burning as demonstrated by health workers at HC hospital (12.7%) and STT (11.4%) (Fig. 17). Respondents noted

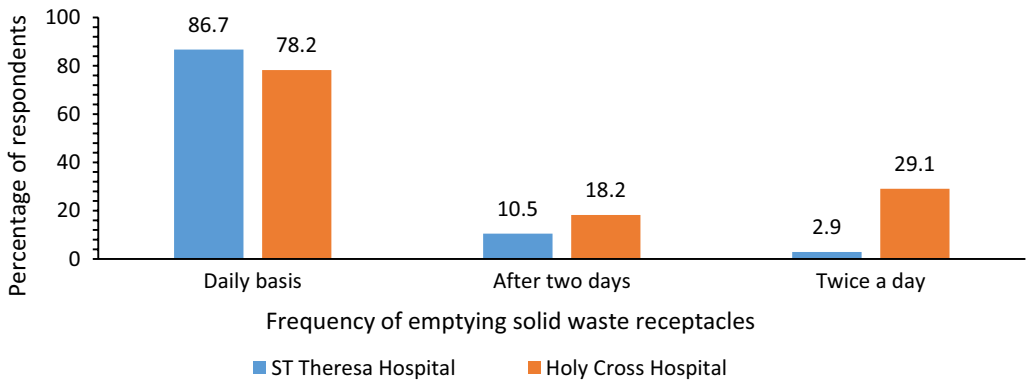

Fig. 14 Frequency of emptying solid waste receptacles at ST Theresa and Holy Cross hospitals Source: Field data (2023)

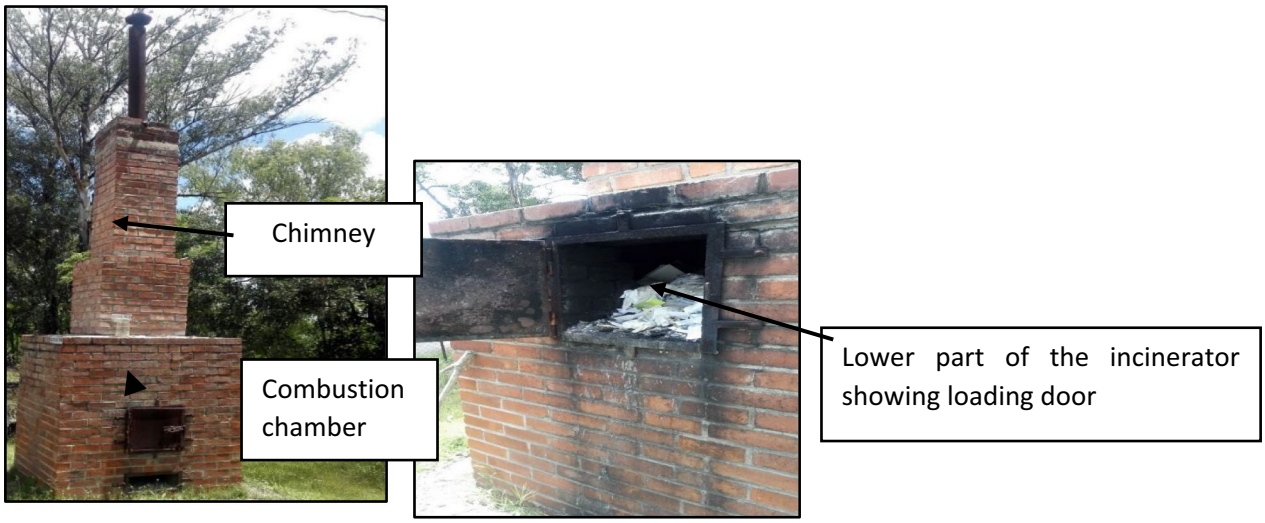

Fig. 15 Incinerator used to dispose medical waste at Holy Cross hospital Source: Field data (2023)

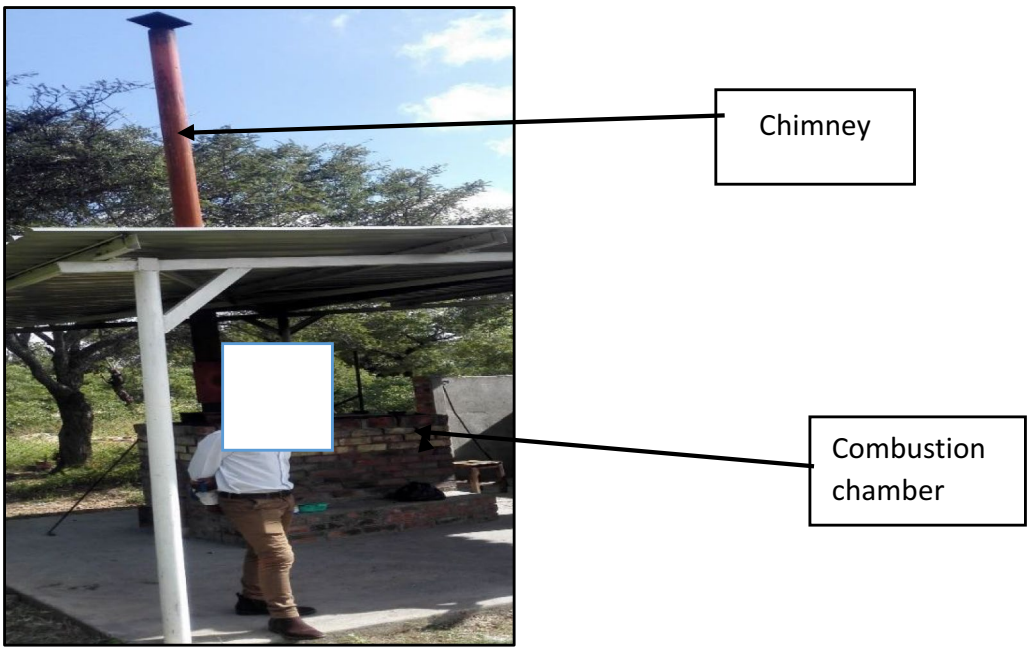

Fig. 16 Incinerator used to dispose solid waste at ST Theresa hospital. Source: Field data (2023)

that a certain fraction of solid waste namely papers, plastics, sachets of pharmaceuticals and contaminated materials like swabs, cotton wool and textiles were disposed through open burning**.** Open combustion of solid waste is also common at rural hospitals in Pakistan [70, 70]. However, open burning of solid waste generates various pollutants with potential to cause air pollution. Gases like nitrous oxide, carbon dioxide and carbon monoxide generated from waste combustion cause air pollution translating to respiratory ailments [64, 88]. Respondents at STT (16.2%), HC (16.4%) supported by hospital EHTs stipulated that solid waste such as food waste like rice, sadza, vegetable and fruits were disposed in open pits. This entails that open pits were highly meant for organic waste at these rural hospitals. Findings concur with Kwikiriza et al. [45]'s studies which illustrate that open pits are among disposal strategies used at rural hospitals in Uganda. Nevertheless, due to inappropriate

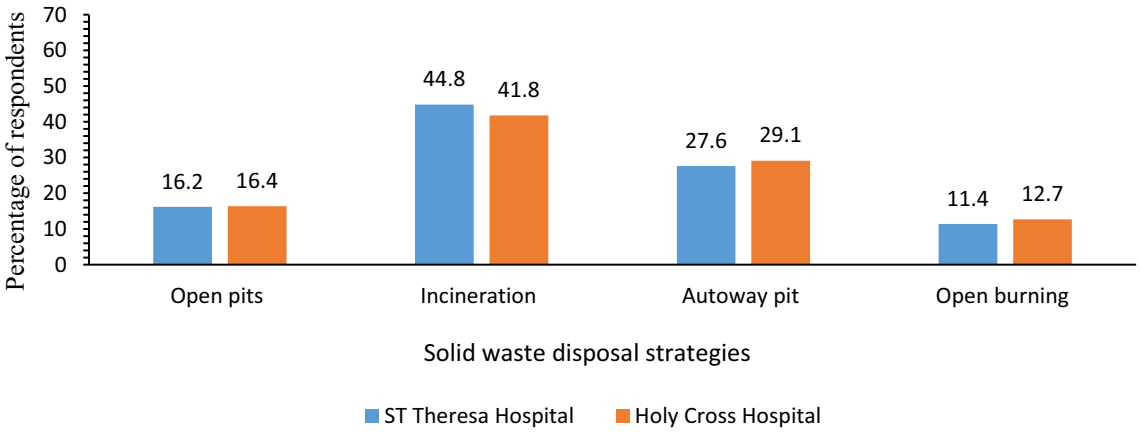

Fig. 17 Hospital solid waste disposal strategies Source: Field data (2023)

Fig. 18 Autoway pit (*located in a minor orchard*) used to dispose pathological waste at Holy Cross hospital Source: Field data (2023)

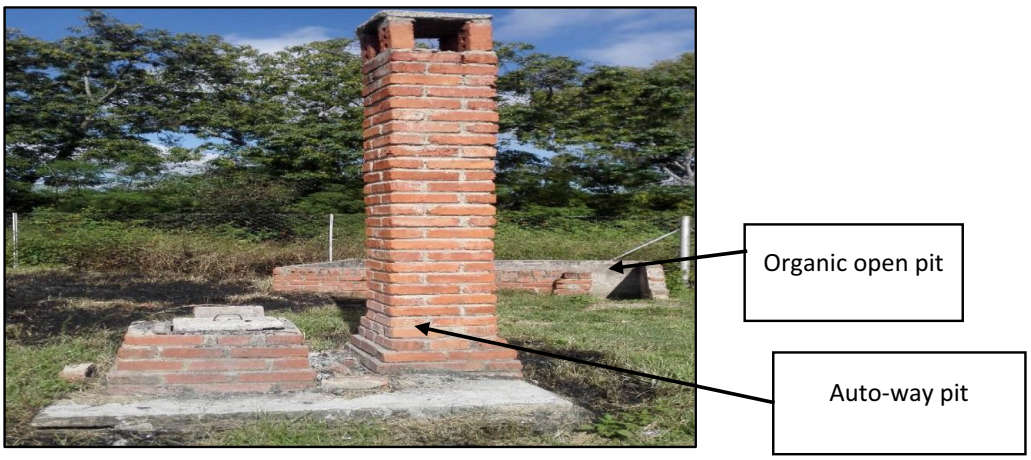

Fig. 19 Autoway pit and organic open pit used to dispose pathological waste and organic waste respectively at ST Theresa hospital Source: Field data (2023)

monitoring and indiscriminate disposal of waste at STT and HC, the pits are acting as breeding sites for vectors. This is in line with Jerie [38] that poorly managed dumpsites offer fertile breeding sites for flies with potential to transmit pathogens which cause diseases to people. To worsen the scenario, observations indicated that non-organic and organic waste was disposed together in an open pit (Fig. 20). Indiscriminate disposal of solid waste at HC and STT hospitals was postulated by EMA Officer. Discarding non-degradable hospital waste into organic pits shortens the lifespan of organic pits, thus worsening solid waste management at STT and HC. The study results coincide with findings at rural health institutions in KwaZulu Natal, South Africa [55].

Awareness of solid waste management legislation and policies among health workers at ST Theresa and Holy Cross hospitals

Majority of the respondents at HC (58.2%) and 54.3% at STT have little knowledge regarding legislation and policies governing hospital solid waste management (Fig. 21). The EMA officer asserted that most health workers' legal frameworks awareness is low. Inadequate knowledge related hospital waste management among health workers worsens problems in waste management at these rural hospitals. Results tallies with Doylo et al. [22]'s studies where rural health workers in Eastern Ethiopia demonstrate less awareness of solid waste legislation and policies. Interview results indicated that negative attitudes among health workers also hinder appropriate solid waste management at STT and HC hospitals. Lack of knowledge regarding legal framework exacerbate challenges in management of waste [15, 40] not excluding management of solid waste from rural hospitals. A total of 45.7% at STT and 41.8% at HC had good knowledge on legislation and policies linked to hospital solid waste management. This concurs with EHTs who indicated that aspects related to hospital solid waste legislation are covered during workshops and training. This congruence with Mmereki [53]'s research that in Botswana

Fig. 20 Disposed solid waste consisting of organic waste and inorganic waste (plastics and papers) in organic pit in Plate 8 at ST Theresa hospital Source: Field survey (2023)

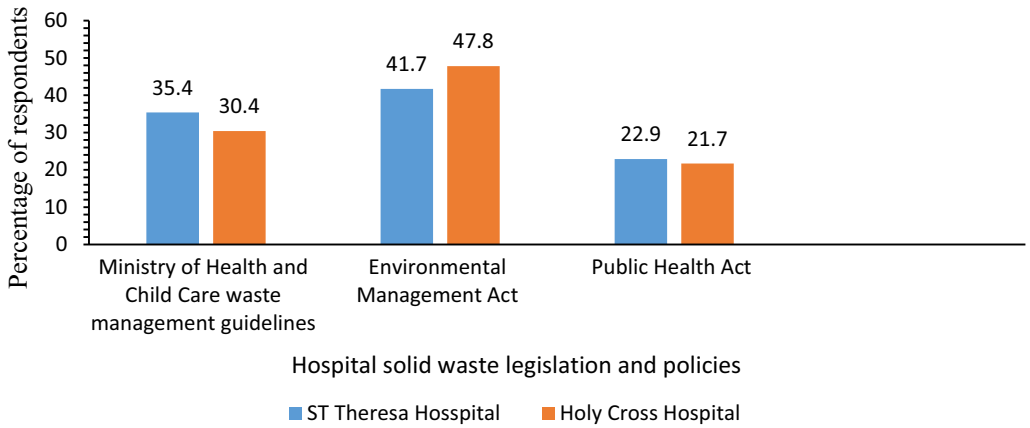

Fig. 21 Hospital solid waste management legislations and policies indicated by health workers Source: Field data (2023)

information related to solid waste including medical waste is disseminated through workshops and training.

Respondents who were aware of legislations and policies at STT hospital (41.7%) and HC hospital (47.8%) noted the Environmental Management Act (Fig. 21). However, 22.9% and 21.7% at STT and HC hospitals, respectively, were aware of the Public Health Act. The EHT alluded that disposal of hospital solid waste utilizing approaches which affect human health negatively was prohibited by Public Health Act. MoHCC waste management guidelines were stipulated by 35.4% and 30.4% respondents at STT and HC, respectively. Therefore, like other developing countries, management of solid waste from rural hospitals of Zimbabwe should conform to guidelines. However, existing legislations and policies are lacking clear issues directed to the responsibility of local authorities when it comes to management of waste from rural health institutions. In terms of legislation linked to hospital solid waste management, the EMA officer mentioned EMA Act Chapter 20:27 which upheld protection of the environment from all forms of pollution. According to the EMA officer, Atmospheric Pollution Prevention Act Chapter 20:03 and Hazardous Substances and Articles Act Chapter 15:05 are applied. Applicability of these Acts was attributed to the fact that some disposal strategies used at these rural hospitals cause air pollution while hazardous solid waste is generated. Results are upheld by studies which indicated that EMA is accountable for monitoring various environmental issues including solid waste management in Zimbabwe (Jerie, [98]; [48]). This signifies that EMA has an upper hand in management of solid waste including waste from rural hospitals. However, achievement of proper solid waste management at rural hospitals requires participation and co-operation of various stakeholders.

In terms of conformity to solid waste legislation and policies, 25.0% respondents at STT and 21.7% at HC consider it as moderate (Fig. 22). This was supported by HC EHT that although they experienced shortage of resources, they tried to maintain recommended standards. Similarly, adequate conformity to solid waste management legislations is limited by lack of resources at rural hospitals in Uganda [45] and Nigeria (Abubakar et al. [104]). Participants at STT (16.7%) and 13.0% at HC hospitals argued that solid waste management strategies conform to a larger extent (Fig. 22). A minor percentage of these respondents indicated that these rural hospitals give less priority to solid waste management. This was supported by respondents at HC (47.8%) and STT (45.8%) who noted that they conform but to a lesser extent. Hence, approaches utilized to manage solid waste at hospitals conform to existing legislation and policies but to a limited degree compared to recommended standards. This concurs with Khan et al. [102] and [62] that owing to various challenges including giving less attention to legislations, solid waste management at rural hospitals is far from sustainability. The EMA officer argued that hospitals focus much on delivering health services while neglecting sustainable solid waste management. For these rural hospitals to direct enough resources to waste issues, health workers must be informed that waste related diseases add burden to health institutions. Inadequate conformity was also indicated by chimneys of the incinerators which were far from recommended standards. This suggests that incinerators used at these rural hospitals have potential to cause air contamination translating to occurrence of respiratory diseases. This concurs with Khudhair [44] and Kwikiriza et al. [45] that improperly constructed incinerators generate dioxins, furans and gases which cause detrimental impacts to human well-being.

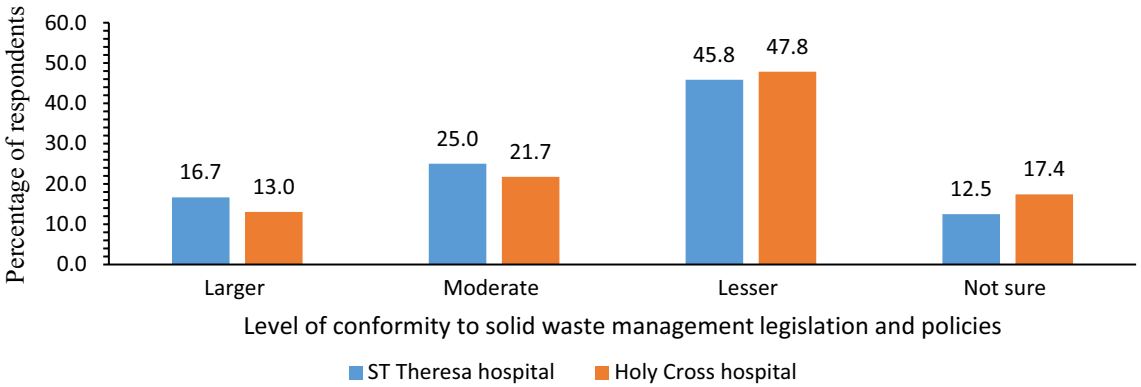

Fig. 22 Adherence or conformity of hospitals to solid waste management policies and legislations. Source: Field data (2023)

Nature of existing solid waste management frameworks at ST Theresa and Holy Cross hospital

Results of the study demonstrated that STT hospital and HC hospitals have an already existing solid waste management system as shown by 100% of the respondents. This demonstrated that these hospitals have their way of managing solid waste. A scenario noted at rural hospitals in South West, Uganda (Kwikiriza et al. [45]). Although from an environmental perspective and sustainability the framework was surrounded by various questions. Respondents at STT (73.3%) and HC (69.1%) hospitals and EMA officer described the system highlighting generation, storage, collection and disposal. It is clear that these rural hospitals put much emphasis on traditional linear solid waste management approaches. Traditional waste management system is an approach that lacks coordination among stakeholders, while giving less attention to waste minimisation techniques [77, 78]. Interview results revealed that existing management systems consider reuse as a peripheral aspect, therefore, a large quantity of solid waste is disposed. This means pinning the circular economy concept in solid waste management at rural hospitals is at an embryonic stage and needs sufficient attention. Mandevere and Jerie [94] asserted that in Zimbabwe about 90% of solid waste is disposed, not excluding waste from health institutions. EHTs expressed the aspect of composting organic waste which was later used as organic manure in the hospital garden. However, observations indicated that proper application of composting was difficult due to indiscriminate management of solid waste in these hospitals. This congruence with …… that appropriate management of solid waste from hospitals is impeded by co-storage of solid waste. A total of 26.7% and 30.9% of respondents at STT and HC hospital, respectively, asserted that reuse was also applied. They mentioned reuse of soft drink and cooking oil containers to store water, giving food waste to those who want to feed their domestic animals namely dogs and chicken. Similarly, in Tanzania food waste from Mwananyamala Regional Referral hospitals was collected and used as animal feeds [35].

The HC Cleaning supervisor indicated that some papers and plastics are collected by health workers and used as fuel when making fire, specifically in this era where load shedding is high. This contradicts with the EMA Officer's view that almost all the waste generated at STT and HC hospitals was disposed. Furthermore, STT hospital EHTs and the Cleaning supervisor's views coincide that the existing solid waste management system has been implemented since 1957 when the hospital was constructed. Hence, most of the waste management approaches used at these institutions are failing to meet demands of the twenty-first century, specifically the SDGs and Zimbabwe NDS 1. Consequently, it is clear that prevailing management techniques may fail to handle current quality and quantity of solid waste at these rural hospitals. Therefore, management approaches which meet sustainable goals as well as Environmental Management Agency objectives are essential. Nevertheless, HC Matrons argued that their EHT was capable of leading implementation of recommended management approaches but shortage of resources was a barrier. Moreover, a large number of respondents at STT (40.0%) and 41.8% HC hospitals illustrated that shortage of resources drives utilisation of existing systems (Fig. 23). This goes in line with studies conducted in Malawi which indicated that rural hospitals are affected by shortage of resources [29]. However, health workers at STT (20.0%) and HC (25.5%) hospitals revealed that adoption of the existing management strategies

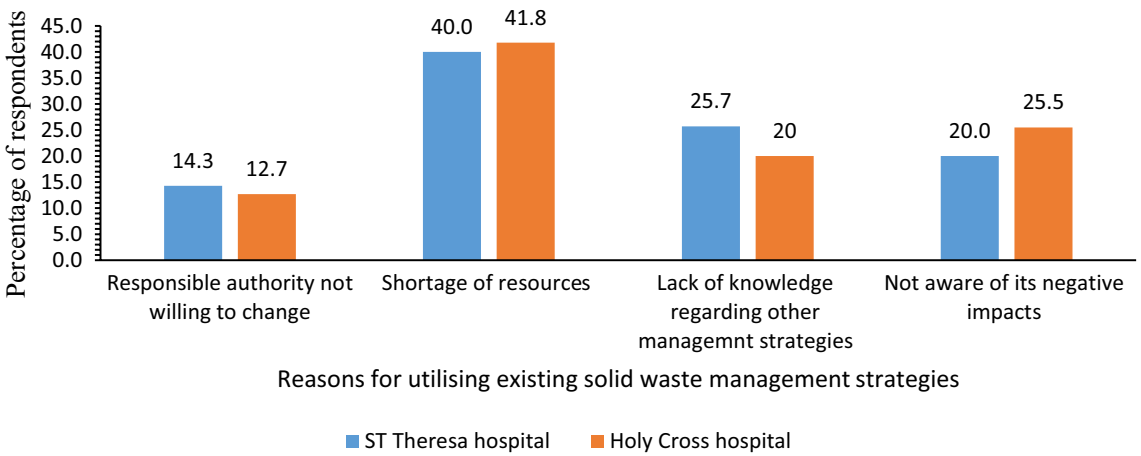

Fig. 23 Reasons for adopting and utilizing existing solid waste management strategies. Source: Field data (2023)

was ascribed to lack of awareness concerning negative impacts of the existing system. Although, respondents at STT (25.7%) and HC (202%) hospitals argued that existing strategies were accredited to lack of knowledge about other strategies. This entails that disseminating adequate knowledge to health workers is one of the solutions to deal with solid waste from rural hospitals. Equally, limited knowledge impedes application of proper solid waste management at rural hospitals in Limpopo province in South Africa [62]. Participants at HC (12.7%) and STT (14.3%) (Fig. 23) asserted that responsible authority was less willing to change the system, since they are almost conservative. This signifies that management of solid waste at these rural hospitals is a top-down approach where involvement of most health workers is low. Correspondingly, equal participation of all health workers in solid waste management issues is rare at rural health institutions in Egypt (Muhammed et al. 2019). Therefore, to achieve sustainability a framework which calls for all stakeholder inclusion in waste management is significant at hospitals under study.

Results indicated that frameworks utilized at HC and STT hospitals consider stakeholders involvement and participation as less important. There was limited room for all health workers to participate in solid waste management aspects at STT (79.0%) and HC (76.4%) (Fig. 24). Inclusion of all stakeholders in management of solid waste is still at a miniature stage at these rural hospitals. Results concur with findings at rural district hospitals in KwaZulu Natal, South Africa [61]. STT hospital's EHT argued that planning for solid waste management issues was the responsibility of the "*Infection Control Team*" and the EHT. Although the DMO suggested that every health worker was expected to participate and contribute towards proper management of hospital solid waste. Taking this into account, solid waste management approaches used at STT and HC sometimes contradict MoHCC as well as WHO requirements. Integrated approach can facilitate networking of various stakeholders and techniques which narrow the route to sustainability.

Health workers receive solid waste management training at STT (83.8%) and at HC (83.6%) hospitals. STT and HC hospitals EHT articulated that health workers are offered training linked to solid waste management. Findings are similar to studies carried out by Hossain et al. [36] in Gopalganj Sadar in Bangladesh. Considering these verdicts, hospital solid was supposed to be managed appropriately although the existing scenario was almost opposite. STT hospital EHT posits that solid waste management training was offered on a monthly basis although new staff members receive training as per request from hospital authority. Respondents at STT (16%) and HC (16%) stipulated that waste management training was done on a monthly basis. This goes in line with [77, 78] that health workers at rural hospitals receive waste management training on a monthly basis. However, most of the health workers at HC hospital (37%) and STT hospital (42%) suggested after a month and above. Considering this, it was clear that frequency of training intervals could not be sufficient to raise awareness of health workers. People involved in managing waste from medical institutions should receive training frequently to increase their awareness (Oyekale and Oyekale, [103], Khan et al. [102]). Participants at STT (35%) and HC (26%) revealed that frequency and intervals of training were not known, hence unclear (Fig. 25). Therefore, training activities can be described as erratic, inadequate and inconsistent resulting in continuous unawareness of health workers. Unawareness of health workers on aspects related to management of solid waste is mostly owed to inadequate training and educational workshops [7, 36].

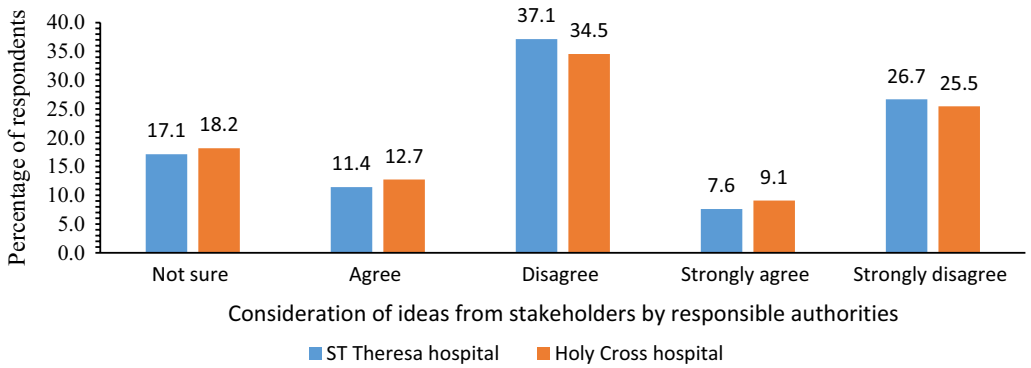

Fig. 24 Perceptions of respondents on consideration of ideas from various stakeholders during hospital solid waste management planning. Source: Field data (2023)

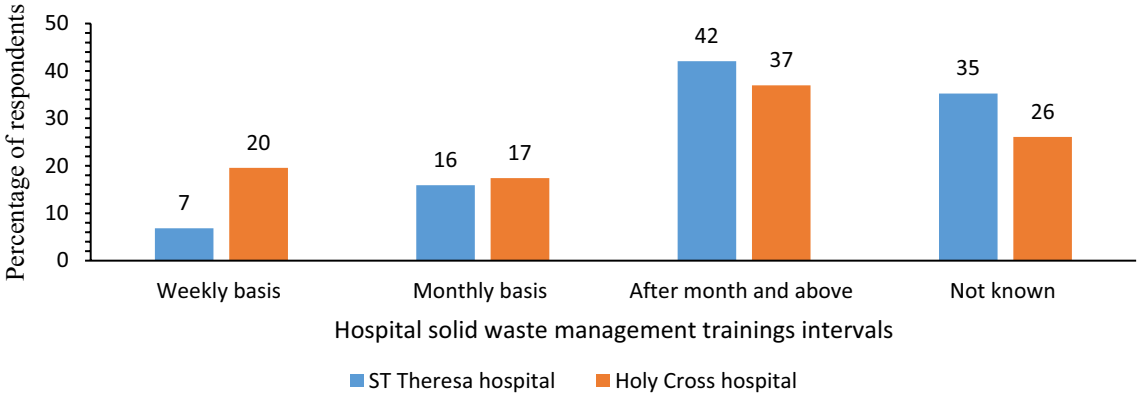

Fig. 25 Solid waste management training intervals ST Theresa and Holy Cross hospitals. Source: Field data (2023)

Effectiveness of existing solid waste management approaches at ST Theresa and Holy Cross hospitals

Rating the effectiveness of hospital solid waste management strategies was carried out utilizing phrases such as low, average, high, very high and very low. A significant quantity of participants at STT hospital (31.4%) and HC hospital (30.9%) show that the effectiveness was on average (Fig. 26). This asserted that effectiveness of the management techniques was regarded as close to standard. This contradicts with participants at STT hospital (26.7%) and HC (23.6%) who suggested that the effectiveness was low. This suggests that solid waste management strategies at HC and STT hospitals are far from sustainability, hence is termed less effective. Findings congruence with research carried out at health institutions in African countries [19] and those in rural areas are encompassed. Most of the disposal approaches utilized occupy the lower base of the waste management hierarchy hence have potential to cause environmental health problems. This signifies that achievement of sustainable goals namely life below water, life on land, clean water and sanitation among others remain difficult if less attention is given to solid waste from rural hospitals. In Zimbabwe, disposal of solid waste from medical facilities is highly centered on strategies which are least recommended by waste management hierarchy [74–78]. EMA Officer highlighted that effectiveness of solid waste management strategies at HC and STT was almost below the expected standards, particularly ZMoHCC and WHO guidelines. A view supported [20] and Chisholm et al. [19] that management of solid waste from hospitals in developing nations usually contradicts with required standards. This was also confirmed by participants at Holy Cross hospital (18.2%) and ST Theresa hospital (18.1%) who pointed the level of effectiveness as very low (Fig. 26). This entails that solid waste management methods at STT and HC hospitals are surrounded by loopholes. Hence, from an environmental and socio-economic perspective efficiency of existing solid waste management is insufficient. Approaches to enhance efficiency of management techniques used

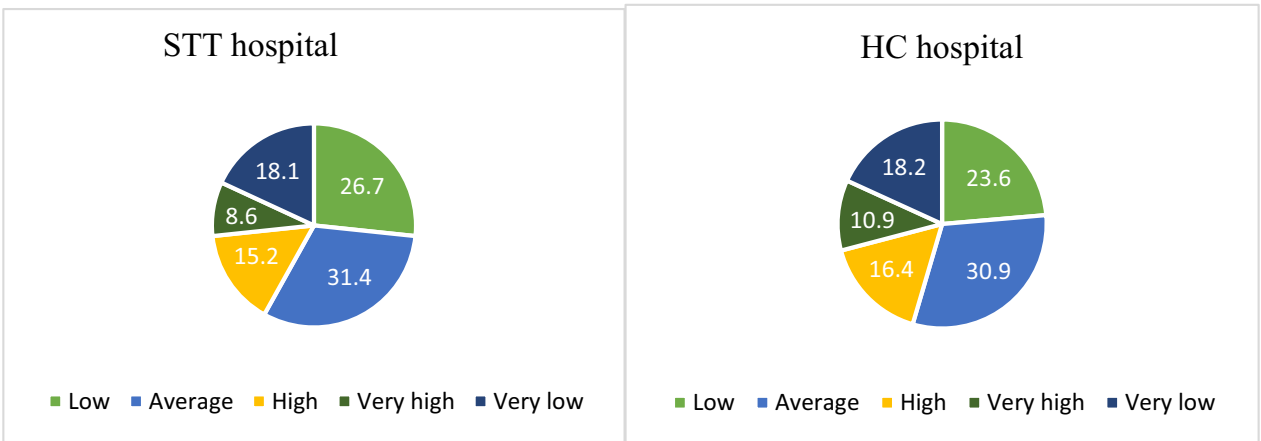

Fig. 26 Effectiveness of hospital solid waste management strategies used at ST Theresa and Holy Cross hospitals Source: Field data (2023)

at rural hospitals are paramount to attain the goal which calls for sustainable cities and communities. This presents the need for an integrated sustainable solid waste management framework at these hospitals. An issue also raised by [75, 76] that to achieve proper management of solid waste from hospitals an integrated framework is essential.

Challenges in management of solid waste management at Holy Cross and ST Theresa hospitals

Solid waste was increasing as noted by health workers at HC (23.6%) and STT (22.9%) hospitals (Fig. 18). The EMA Officer and hospital EHTs postulated that increase of solid waste at HC and STT hospital was a major challenge. Consequently, methods to insight health workers on how to minimize the quantity of solid waste generated at these rural hospitals. According to EHTs, the management of solid waste is exacerbated by a sharp increase of waste, particularly infectious waste. To worsen the situation, the quantity of solid waste overwhelmed capacity of available resources translating to improper management at rural hospitals under study. Solid waste quantity which overstrained existing resources was also noted at rural hospitals in South Africa [26]. Inappropriate management of solid waste was attributed to inadequate finance as upheld by respondents at STT (38.1%) and 30.9% at HC hospitals (Fig. 27). Financial shortages hinder availability of waste storage receptacles, construction of proper disposal sites, provision of enough PPE/C to involved people and hiring of enough workers responsible for waste management at rural hospitals. Questionnaire and interview results concur that limited finance was a major barrier to achieve proper management of solid waste at STT and HC. Financial problems are also experienced at rural health institutions in African countries like Botswana [57]. Participants at HC (20.0%), STT (15.2%) and the EMA Officer asserted that difficulties in management of solid waste was a result of unawareness among health workers. This implies that strategies to enlighten health workers about hospital solid waste issues are essential to reach sustainability. The reason being lack of awareness is among major challenges in hospital solid waste management in developing nations (Behnam et al. 2020; [80]

In addition, respondents at HC (9.1%) and STT (10.5%) blamed responsible authorities for giving less attention to solid waste management (Fig. 27). This blame game increased fragmentation of the prevailing solid waste management system while exacerbating non-participation of other health workers in waste management issues. Results demonstrated that participants at HC (16.4%) and STT (13.3%) hospitals argued that shortage of skilled labour was among barriers faced during solid waste management. Limited availability of skilled labour increases difficulties faced during implementation of strategies which calls for appropriate solid waste management. This suggests that adoption of techniques like recycle, reuse and energy recovery methods is difficult owing to limited skills among responsible people. This is among reasons why STT and HC rural hospitals put much emphasis on management strategies which give less attention to the circular economy. Verdicts are supported by Zhang et al. [91] and Aycin and Kayapinar [13] that in the context of solid waste management, adoption of management techniques which uphold circular economy require

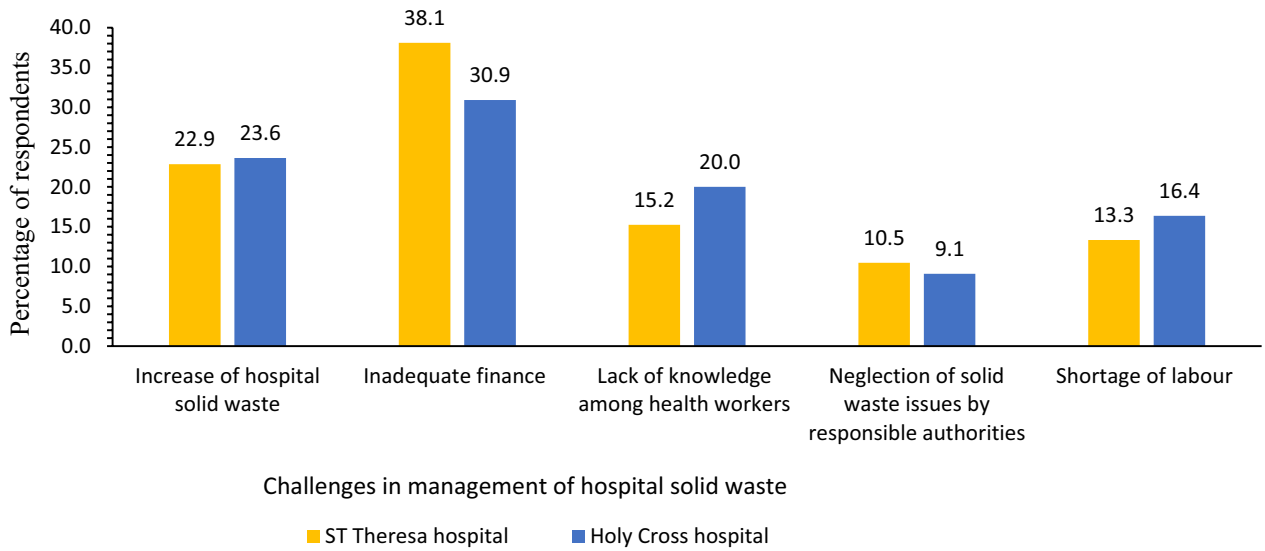

Fig. 27 Challenges faced by STT and HC hospitals in management of solid waste Source: Field data (2023)

co-operation, involving people with required skills. HC hospital EHT pointed out that improper separation at generation source causes various problems during solid waste management. Considering hazardous and non-hazardous characteristics of solid waste from STT and HC rural hospitals, management of mixed waste was problematic, particularly disposal. Disposal was difficult since different types of hospital solid waste needs its unique discarding technique. Inappropriate segregation intensifies problems in management of waste at rural hospitals in Darjeeling district, India [14] and at rural hospitals in Pakistan [70, 70]. Hospital EHTs indicated use of substandard disposal infrastructure as the root cause of solid waste management complications. Utilisation of incinerators with cracked combustion chambers (Fig. 28) facilitates incomplete combustion, resulting in air pollution. Incinerator operator argued that cracking of the incinerator was attributed to use of general cement and bricks instead of fire-resistant bricks and cement. Hence, failure to include other health workers during planning was one of the challenges which fueled inappropriate disposal of solid waste at STT and HC. Findings are supported by Serge-Kubanza and Simatele [72] and Batista et al. [15]'s studies that failure to include all stakeholders is among the root causes of waste mismanagement. To achieve sustainable management of solid waste at rural hospitals under study, hospital authorities are recommended not to over emphasise the need for all-stakeholder participation.

Conclusion and recommendations

Solid waste generated at rural hospitals in Chirumanzu district is a replica of waste from urban hospitals. STT and HC hospitals generate both hazardous and non-hazardous solid waste. Hazardous solid waste produced comprises pharmaceuticals, toxic chemicals, pathological, hospital radioactive waste, sharps and cytotoxic waste. Non-hazardous waste includes general solid waste in the form of uncontaminated papers, plastics, food remains, textiles and soft drink bottles. At STT and HC hospitals, solid waste was produced from hospital wards, kitchen, out-patient departments, emergency rooms, x-ray department, laboratory, hospital pharmacy, offices and laundry. Pharmaceutical solid waste generated encompasses contaminated and outdated drugs while pathological waste includes placentas, still foetuses and detached body parts. Sharp waste in the form of syringes, infusion sets, broken glasses, needles, razor blades, scalpels, nails, pipettes and knives were produced. Toxic chemicals like disinfectants, reagents and film developers whereas radioactive waste such materials contaminated radionuclides during cancer and tumour growth treatment. Infectious waste produced comprises soiled and used plaster caster, cotton wools, gloves, swabs, masks, aprons, hospital caps, beddings, dressings, goggles, and specimen containers. Infectious waste produced at the hospitals was suspected to contain pathogens. Treatment and disinfection of infectious waste was done through chlorination and autoclaving, although the strategies were rarely applied due to indiscriminate storage of waste.

Fig. 28 Cracked incinerator used to dispose solid waste at ST Theresa hospital Source: Field data (2023)

Storage of non-segregated waste was observed in waste receptacles namely pedal operated bins, metal and plastic buckets and cardboard boxes. However, sharps were stored in sharp containers. Solid waste storage containers were transported to the hospital disposal site using wheelbarrows and manual handling of containers. Solid waste was disposed through open burning, dumping, incineration and into open pits as well as auto-way pits, although solid waste was observed at illegal sites at these rural hospitals. Chirumanzu district rural hospitals are focusing much on disposal approaches which occupy the base of the waste management hierarchy. Hence disposal techniques have potential to cause air, soil, water contamination while exposing people to respiratory, skin and intestinal health problems. Relying on these disposal strategies at rural hospitals is attributed to various challenges namely inadequate finance, skilled labour, lack of commitment among responsible authority and insufficient awareness among health workers. Although the scenario is worsened by limited participation of all health workers in waste management issues. As a result, from an environmental perspective, existing management strategies are far sustainability demands. To narrow the route to achieve sustainable solid waste management at these rural hospitals, an integrated approach is significant. There is a need for Environmental Management Agency Officers, Hospitals Environmental Health Department staff, all health workers to collaborate and deal with the existing situation. ZMoHCC and

the Zimbabwe Ministry of Finance must work together to channel enough resources to solid waste management at rural hospitals, particularly STT and HC. Enough resources enable hospitals to invest in waste management approaches which support a circular economy, thus propelling economic growth while limiting the quantity of disposed waste.

Author contributions
Data collection, analysis and writing of the original draft was done by TS. TVM was responsible for supervising, reviewing and analysis of the paper while TS was responsible for data collection.

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Data utilized during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical approval and consent to participate
Approval was granted by Midlands State University and Chirumanzu District Medical Officer to carry out the research as well as to publish under its name. All sources were properly acknowledged. All authors participated and agreed to participate up to the final revision of the manuscript.

Consent for publication
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The authors declare no competing interests.

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References

1. Aborigo RA, Reidpath DD, Oduro AR, Allotey P (2018) Male involvement in maternal health: perspectives of opinion leaders. BMC Pregnancy Childbirth 18(1):1–10
2. Abubakar, A. (2021). Environmental and health implications of management of medical wastes in selected hospitals in Niger state, Nigeria (Doctoral dissertation).
3. Adelodun B, Ajibade FO, Ibrahim RG, Ighalo JO, Bakare HO, Kumar P, Choi KS (2021) Insights into hazardous solid waste generation during COVID-19 pandemic and sustainable management approaches for developing countries. J Mater Cycles Waste Manage 23(6):2077–2086
4. Afolabi AS, Agbabiaka HI, Afon AO, Akinbinu AA, Adefisoye EA (2018) Solid waste management practice in obafemi awolowo university teaching hospital complex (OAUTHC), Ile-Ife, Nigeria. Manage Environ Qual Int J 29(3):547–571
5. Ahmad R, Liu G, Santagata R, Casazza M, Xue J, Khan K, Lega M (2019) LCA of hospital solid waste treatment alternatives in a developing country: the case of district Swat. Pakistan Sustain 11(13):3501
6. Akkajit P, Romin H, Assawadithalerd M (2020) Assessment of knowledge, attitude, and practice in respect of medical waste management among healthcare workers in clinics. J Environ Publ Health. https://doi.org/10.1155/2020/8745472
7. Ali M, Wang W, Chaudhry N, Geng Y (2017) Hospital waste management in developing countries: a mini review. Waste Manage Res 34:87–90
8. Almusawi MBH, Karim ATBA, Ethaib S (2022) Evaluation of construction and demolition waste management in Kuwait. Recycling 7(6):88
9. Angmo, S. and Shah, S. (2020). Assessment of waste to energy generation potential of municipal solid waste: a case study of South Delhi. J Sci Technol 5(5).
10. Ansari M, Ehrampoush MH, Farzadkia M, Ahmadi E (2019) Dynamic assessment of economic and environmental performance index and generation, composition, environmental and human health risks of hospital solid waste in developing countries; a state of the art of review. Environ Int 132:105073
11. Aragaw TA, De-la-Torre GE, Teshager AA (2022) Personal protective equipment (PPE) pollution driven by the COVID-19 pandemic along the shoreline of Lake Tana, Bahir Dar Ethiopia. Sci Total Environ 820:153261
12. Awodele O, Adewoye AA, Oparah AC (2016) Assessment of medical waste management in seven hospitals in Lagos. Nigeria BMC Publ Health 16(1):1–11
13. Ayçin E, Kayapinar KS (2021) Towards the circular economy: analysis of barriers to implementation of Turkey's zero waste management using the fuzzy DEMATEL method. Waste Manage Res 39(8):1078–1089
14. Bakshi R, Ghosh N, Mukherjee R, Chakraborty S (2018) Assessment of knowledge and practice of biomedical waste management among health care personnel in a rural tertiary care hospital of Darjeeling District, West Bengal. India J Comprehensive Health 6(1):14–18
15. Batista M, Caiado RGG, Quelhas OLG, Lima GBA, Leal Filho W, Yparraguirre ITR (2021) A framework for sustainable and integrated municipal solid waste management: Barriers and critical factors to developing countries. J Clean Prod 312:127516
16. Bowley AL (1926) Measurements of precision attained in sampling. Bull Int Stat Inst 22:1–62
17. Bundhoo ZM (2018) Solid waste management in least developed countries: current status and challenges faced. J Mater Cycles Waste Manage 20:1867–1877
18. Chireshe A, Kowe P, Musasa T, Shabani T, Shabani T, Moyo SB (2023) Assessment of ergonomic risks among refuse collectors in municipalities of Harare District Zimbabwe. Safety Extreme Environ. https://doi.org/10.1007/s42797-023-00085-5
19. Chisholm JM, Zamani R, Negm AM, Said N, MahmoudAbdel daiem M, Dibaj M, Akrami M (2021) Sustainable waste management of medical waste in African developing countries: a narrative review. Waste Manage Res. 39(9):1149–1163
20. Das AK, Islam MN, Billah MM, Sarker A (2021) COVID-19 pandemic and healthcare solid waste management strategy–a mini-review. Sci Total Environ 778:146220
21. Debalkie D, Kumie A (2017) Healthcare waste management: the current issue in Menellik II referral Hospital. Ethiopia Curr World Environ 12(1):42–52
22. Doylo T, Alemayehu T, Baraki N (2019) Knowledge and practice of health workers about healthcare waste management in public health facilities in Eastern Ethiopia. J Commun Health 44:284–291
23. Edward, A. (2021). Assessment of Health Care Workers' Knowledge Attitudes and Practices for Effective Management of Biomedical Waste in Dodoma City Tanzania (Doctoral dissertation, The Open University of Tanzania).
24. EPA. (2020). Sustainable Materials: non-hazardous materials and waste management hierarchy. www.epa.gov Accessed Jan 2023.
25. Erdogan AA, Yilmazoglu MZ (2021) Plasma gasification of the medical waste. Int J Hydrogen Energy 46(57):29108–29125
26. FC, O., JS, O. and TG, T. (2018). A review of medical waste management in South Africa. Open Environ Sci. 10(1).
27. Fernando RLS (2019) Solid waste management of local governments in the Western Province of Sri Lanka: an implementation analysis. Waste Manage 84:194–203
28. Frieden M, Zamba B, Mukumbi N, Mafaune PT, Makumbe B, Irungu E, Prasai M (2020) Setting up a nurse-led model of care for management of hypertension and diabetes mellitus in a high HIV prevalence context in rural Zimbabwe: a descriptive study. BMC Health Serv Res 20:1–10
29. Gajewski J, Bijlmakers L, Mwapasa G, Borgstein E, Pittalis C, Brugha R (2018) 'I think we are going to leave these cases obstacles to surgery in rural Malawi: a qualitative study of provider perspectives. Trop Med Int Health 23(10):1141–1147

30. Ghimire HP, Dhungana A (2018) A Critical analysis on hospital waste management at Bandipur Hospital, Bandipur Tanahu District. Nepal J Gandaki Medical College-Nepal 11(02):41–45
31. Ghosh SK, Mersky RL, Ghosh SK, Di Maria F (2022) Waste management during pandemic of COVID-19 in India, Italy, and the USA: the influence of cultural perspectives in health care waste Management and COVID 19 pandemic policy. Implementation Status and Vaccine Management Springer Nature, Singapore
32. Grabois TM, Caldas LR, Julião NR, Toledo Filho RD (2020) An experimental and environmental evaluation of mortars with recycled demolition waste from a hospital implosion in Rio de Janeiro. Sustainability 12(21):8945
33. Gu B, Wang H, Chen Z, Jiang S, Zhu W, Liu M, Bi J (2015) Characterization, quantification and management of household solid waste: a case study in China. Resour Conserv Recycl 98:67–75
34. Hannan MA, Aigbogun O (2021) Hazardous waste management situation in Bangladesh: an assessment of existing legal frameworks and challenges through working from Home. Int J Acad Res Business Soc Sci 11(10):24–43
35. Honest A, Saria J (2020) Performance of experimental bio-digestion for pathological and biodegradable waste management at Mwananyamala Regional Referral Hospital Tanzania. J Environ Prot 11(10):838
36. Hossain MR, Islam MA, Hasan M (2021) Assessment of medical waste management practices: a case study in Gopalganj Sadar. Bangladesh Eur J Med Health Sci 3(3):62–71
37. Ilyas S, Srivastava RR, Kim H (2020) Disinfection technology and strategies for COVID-19 hospital and bio-medical waste management. Sci Total Environ 749:141652
38. Jerie S (2016) Occupational risks associated with solid waste management in the informal sector of Gweru, Zimbabwe. J Environ Publ Health. https://doi.org/10.1155/2016/9024160
39. Jerie, S. and Musasa, T. (2022). Solid waste management and the COVID-19 pandemic lockdown in Zvishavane town, Zimbabwe. Ethiopian Journal of Environmental Studies and Management, 15(3).
40. Jerin DT, Sara HH, Radia MA, Hema PS, Hasan S, Urme SA, Quayyum Z (2022) An overview of progress towards implementation of solid waste management policies in Dhaka. Heliyon, Bangladesh
41. Kalantary RR, Jamshidi A, Mofrad MMG, Jafari AJ, Heidari N, Fallahizadeh S, Torkashvand J (2021) Effect of COVID-19 pandemic on medical waste management: a case study. J Environ Health Sci Eng 19:831–836
42. Kalogiannidou K, Nikolakopoulou E, Komilis D (2018) Generation and composition of waste from medical histopathology laboratories. Waste Manage 79:435–442
43. Kanyumba B (2022) Training as a tool for service delivery: a case study of health care workers in Gwanda. Zimbabwe Afr J Inter/Multidiscipl Stud 4(1):384–393
44. Khudhair, H. A. (2018). Modelling, Composition and production rate of medical solid waste in Tikrit: a case study of Tikrit Teaching Hospital (TTH) in Iraq. J Adv Sci Eng Technol (JASET). 1(2).
45. Kwikiriza S, Stewart AG, Mutahunga B, Dobson AE, Wilkinson E (2019) A whole systems approach to hospital waste management in rural Uganda. Front Public Health 7:136
46. Liu P, Rani P, Mishra AR (2021) A novel pythagorean fuzzy combined compromise solution framework for the assessment of medical waste treatment technology. J Clean Prod 292:126047
47. Madiba, M. K. (2022). Prosecution of health care risk waste offenders in terms of South African law (Doctoral dissertation. North-West University (South Africa).
48. Makamba DNJ (2022) Policy gaps on solid waste management: case of Chegutu Municipality Zimbabwe. Policy 5(03):232
49. Malsparo, (2020) Pharmaceutical waste management, https://www.malsparo.com/pharm.htm, Accessed Dec 2023.
50. Manyisa ZM, van Aswegen EJ (2017) Factors affecting working conditions in public hospitals: a literature review. Int J Afr Nursing Sci 6(28):38
51. Marambanyika T, Mupfiga UN, Musasa T, Ngwenya K (2021) Local perceptions on the impact of drought on Wetland Ecosystem services and associated household livelihood benefits: the case of the Driefontein Ramsar Site in Zimbabwe. Land 10(6):587
52. Matsa M, Dzawanda B (2014) Dependency syndrome by communities or insufficient ingestion period by benefactor organizations? The Chirumanzu caritas community gardening project experience in Zimbabwe. J Geograp Earth Sci 2(1):127–148
53. Mmereki D (2018) Current status of waste management in Botswana: a mini-review. Waste Manage Res 36(7):555–576
54. Mohammed H, Abd El-Kader R, Ibrahim A (2019) Knowledge, attitude and practice of health care personnel about medical waste management in selected family health centers in Mansoura. Egypt Int J Innov Res Med Sci (IJIRMS) 4(06):349–356
55. Motlatla M, Maluleke TX (2021) Assessment of knowledge about healthcare risk waste management at a tertiary hospital in the northern cape province, South Africa. Int J Environ Res Public Health 18(2):449
56. Mugandani R, Wuta M, Makarau A, Chipindu B (2012) Re-classification of agro-ecological regions of Zimbabwe in conformity with climate variability and change. Afr Crop Sci J 20:361–369
57. Nkomazana, O. (2022). A healthcare case study from Botswana, Africa. Smart Villages: bridging the global urban-rural divide, 309–319.
58. Noufal M, Yuanyuan L, Maalla Z, Adipah S (2020) Determinants of household solid waste generation and composition in Homs City, Syria. J Environ Publ Health. https://doi.org/10.1155/2020/7460356
59. Nyakatswau ST, Bangure D, Pierre G, Nyika H (2022) Disposal of medical waste: a legal perspective in Zimbabwe. Int J Commun Med Public Health 9:2331–2333
60. Oduro-Kwarteng S, Addai R, Essandoh HM (2021) Healthcare waste characteristics and management in Kumasi. Ghana Sci Afr 12:e00784
61. Olaifa A, Govender RD, Ross AJ (2018) Knowledge, attitudes and practices of healthcare workers about healthcare waste management at a district hospital in KwaZulu-Natal. South African Family Practice 60(5):137–145
62. Olaniyi FC, Ogola JS, Tshitangano TG (2019) Efficiency of health care risk waste management in rural healthcare facilities of South Africa: an assessment of selected facilities in Vhembe District, Limpopo Province. Int J Environ Res Public Health 16(12):2199
63. Osman AM, Ukundimana Z, Wamyil FB, Yusuf AA, Telesphore K (2023) Quantification and characterization of solid waste generated within Mulago national referral hospital, Uganda, East Africa. Case Stud Chem Environ Eng 7:100334
64. Pansuk J, Junpen A, Garivait S (2018) Assessment of air pollution from household solid waste open burning in Thailand. Sustainability 10(7):2553
65. Pratap J, Singh A, Pandey KL (2022) Radioactive waste; source, exposure, and waste management. Emerg Domains Mater Sci 1:73
66. Pujara Y, Govani J, Patel HT, Pathak P, Mashru D, Ganesh PS (2023) Quantification of environmental impacts associated with municipal solid waste management in Rajkot city, India using life cycle assessment. Environmental Advances 12:100364
67. Rahman MM, Bodrud-Doza M, Griffiths MD, Mamun MA (2020) Biomedical waste amid COVID-19: perspectives from Bangladesh. Lancet Glob Health 8(10):e1262
68. Ramírez C, Gonzalez E (2019) Methodological proposal for the interinstitutional management of wastes in health care centers in Uruguay. MethodsX 6:71–81
69. Rupani PF, Nilashi M, Abumalloh RA, Asadi S, Samad S, Wang S (2020) Coronavirus pandemic (COVID-19) and its natural environmental impacts. Int J Environ Sci Technol 17(11):4655–4666
70. Sadia A, Farid MU, Ghafoor A, Nasir Awan A, Maqsood U, Farid MZ (2020) Effective management of hospital and medical waste in rural areas of pakistan: a case study. Waste Energy Technol 2:76
71. Saria JA (2021) Estimation of persistent organic pollutants releases and emission levels from healthcare waste in Mwananyamala and Temeke Regional Hospitals in Tanzania. Huria 28(2):176–191
72. Serge Kubanza N, Simatele MD (2020) Sustainable solid waste management in developing countries: a study of institutional strengthening for solid waste management in Johannesburg, South Africa. J Environ Planning Manage 63(2):175–188
73. Shaban T, Jerie S (2023) A review of the applicability of environmental management systems in waste management in the medical sector of Zimbabwe. Environ Monit Assess 195:789
74. Shabani S, Jerie S (2023) Medical solid waste management status in Zimbabwe. J Mater Cycles Waste Manage 25:1–16

75. Shabani T, Jerie S (2023) A review of the applicability of environmental management systems in waste management in the medical sector of Zimbabwe. Environ Monit Assess 195(6):789
76. Shabani T, Jerie S (2023) A review on the effectiveness of integrated management system in institutional solid waste management in Zimbabwe. Environ Sci Pollut Res 30(45):100248–100264
77. Shabani T, Jerie S, Shabani T (2023) Applicability of the life cycle assessment model in solid waste management in Zimbabwe. Circ Econ Sustain 3:1–21
78. Shabani T, Mutekwa VT, Shabani T (2023) Developing a sustainable integrated solid waste management framework for Rural Hospitals in Chirumanzu District Zimbabwe. Circ Econ Sustain. https://doi.org/10.1007/s43615-023-00313-x
79. Sharma HB, Vanapalli KR, Cheela VS, Ranjan VP, Jaglan AK, Dubey B, Bhattacharya J (2020) Challenges, opportunities, and innovations for effective solid waste management during and post COVID-19 pandemic. Resour Conserv Recycl 162:105052
80. Thakur V, Sharma S (2021) Assessment of healthcare solid waste management practices for environmental performance: a study of hospitals in Himachal Pradesh, India. Manage Environ Quality Int J 32(3):612–630
81. Tripathi A, Tyagi VK, Vivekanand V, Bose P, Suthar S (2020) Challenges, opportunities and progress in solid waste management during COVID-19 pandemic. Case Stud Chem Environ Eng 2:100060
82. Wang J, Shen J, Ye D, Yan X, Zhang Y, Yang W, Pan L (2020) Disinfection technology of hospital wastes and wastewater: Suggestions for disinfection strategy during coronavirus disease 2019 (COVID-19) pandemic in China. Environ Pollut 262:114665
83. World Health Organisation (WHO) and United Nations International Children to Emergency Fund, (UNICEF) (2015) Water, sanitation and hygiene in health care facilities: status in low—and middle-income countries. World Health Organization, Geneva
84. World Health Organisation WHO (2018). Healthcare Waste Fact Sheet Updated February. 2018, Media Centre.
85. World Health Organisation (2020) Water, sanitation, hygiene, and waste management for the COVID-19 virus: in- terim guidance. World Health Organization, Geneva
86. Woromogo SH, Djeukang GG, Yagata Moussa FE, Saba Antaon JS, Kort KN, Tebeu PM (2020) Assessing knowledge, attitudes, and practices of healthcare workers regarding biomedical waste management at biyem-assi district hospital, yaounde: a cross-sectional analytical study. Adv Public Health 2020:1–7
87. Xin X, Zheng X, Lu H, Yang Q, Sun Y, Qu K, He H (2021) A study on the management of needle-stick and sharps injuries based on total quality management in a tertiary hospital in western China. J Vasc Access 22(2):273–279
88. Xiu M, Stevanovic S, Rahman MM, Pourkhesalian AM, Morawska L, Thai PK (2018) Emissions of particulate matter, carbon monoxide and nitrogen oxides from the residential burning of waste paper briquettes and other fuels. Environ Res 167:536–543
89. Yamane T (1967) Statistics: an introductory analysis. Harper and Row, New York
90. Zafar, S. (2019). Medical waste management in developing countries. Bioenergy consult
91. Zhang A, Venkatesh VG, Liu Y, Wan M, Qu T, Huisingh D (2019) Barriers to smart waste management for a circular economy in China. J Clean Prod 240:118198
92. ZIMSTAT (2022) Census 2022: preliminary report. Zimbabwe National Statistics Agency, Harare
93. Zohoori M, Ghani A (2017) Municipal solid waste management challenges and problems for cities in low-income and developing countries. Int J Sci Eng Appl 6(2):39–48
94. Mandevere B, and Jerie S (2018). Household solid waste management: how effective are the strategies used in Harare Zimbabwe. J Environ Waste Management and Recycling. 2018; 2 (1): 16, 22.
95. Shabani T, and Jerie S (2023). Medical solid waste management status in Zimbabwe. Journal of Material Cyclesand Waste Management, 25(2), 717-732.
96. Shabani T, Mutekwa VT, Shabani T (2024). Environmental health risks associated with solid waste management at rural hospitals in Chirumanzu District, Zimbabwe. SN Social Sciences, 4(2), 20.
97. Kori E (2013). An evaluation of environmental sustainability of land reform in Zimbabwe: a case study ofChirumanzu District. Midlands Province (Doctoral dissertation).
98. Jerie, S. (2013) Quo vadis solid waste management legislation in the informal sector of Harare. The Dyke 7(1):37–53.
99. Fakarayi, T., Mashapa, C., Gandiwa, E., Kativu, S. (2015). Pattern of land-use and land cover changes in driefontein grassland important bird area, Zimbabwe', Tropical conservation science, vol 8. SAGE Publications, LosAngeles, pp 274–283.
100. Mmanga, M., Singini, W., Di Bella, V., Flaherty, M.G., Holm, R.H. (2019). Unpacking healthcare waste management at rural village health clinics in the Ntcheu District (Malawi). Environ Monit Assess 191:1–10.
101. Vitthal, P.C., Sanjay, C.S., Sharma, B.R., Ramachandran, M. (2015). Need of biomedical waste management inrural hospitals in India. Int J Pharm Sci Rev Res 35(1):175–179.
102. Khan, B. A., Khan, A. A., Ahmed, H., Shaikh, S. S., Peng, Z. and Cheng, L. (2019). A study on small clinics waste management practice, rules, staff knowledge, and motivating factor in a rapidly urbanizing area. Internationaljournal of environmental research and public health, 16(20), 4044.
103. Oyekale, A. S. and Oyekale, T. O. (2017). Healthcare waste management practices and safety indicators in Nigeria. BMC public health, 17, 1-13.
104. Abubakar, A., Emigilati, M. A., Yahya, I. T. and Muhammed, M. N. (2019). Critical examine hospital wastes management practice in some parts of Niger State, Nigeria. Journal of Environmental Design and construction-management. VOL. 10 NO.4 DEC-2019 ISSN: 2166-3193
105. Agamuthu, P. and Barasarathi, J. (2021). Clinical waste management under COVID-19 scenario in Malaysia. Waste Management & Research, 39(1_suppl), 18-26.
106. Annex, I., Annex, I.I., Annex, I.V., Annex, V.A., Annex, V.B., Annex, V.I., Annex, V.I.I., Annex, V., Annex, I.X.,(1989). Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. https://www.basel.int/Portals/4/Basel%20Convention/docs/text/BaselConventionText-e.pdf.

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