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Assessment of Healthcare Solid Waste Composition, Generation and its Management: the case of Two Hospitals of Shashemene Town, Oromia Regional State, Ethiopia

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General Waste;
Hazardous Waste;
HCW Management;
Solid Waste Generation

Research article

ABSTRACT

Hazardous wastes from Hospitals could pose threat to the health of healthcare workers, the general public and the environment unless managed properly. The study aimed to appraise the healthcare waste (HCW) composition, generation rate and the prevailing management practices in two Hospitals (a Private and a Government owned) of Shashemene Town, Ethiopia. A cross-sectional study involving Direct Observation, Key Informant Interview, Questionnaire survey and Weighting Scale was conducted to evaluate the current HCW management practices and to quantify the HCW generation rate. Data was analyzed using SPSS version 20. The mean generation rates of HCW were 45.2 ± 5.8kg day–1 (0.20kg bed–1day–1) and 20 ± 2.4 kg day–1 (0.19kg bed–1day–1) from Government Hospital (GH) and Private Hospital (PH), respectively. Of the total solid waste generated, over half (GH: 53.3%; PH: 57.1%) constituted general waste (GW), and the remaining (GH: 46.7%; PH: 42.9%) comprised hazardous waste (HW), which exceeded the WHO threshold (10–25%) intimates the lack of poor waste segregation. There were significant variations between the hospital wards regarding GW (GH: $\chi2 = 31$; $P < 0.001$; PH:$\chi2 = 13$; $P < 0.01$), HW (GH: $\chi2 = 25$; $P < 0.001$; PH: $\chi2 = 10$; $P < 0.01$), and total HCW (GH: $\chi2 = 46$; $P < 0.01$; PH: $\chi2 = 22$; $P < 0.01$). Besides, significant differences were observed between the mean total HCW ($\chi2 = 9.016$;$P < 0.01$), GW ($\chi2 = 9.8$; $P < 0.01$) and the HW ($\chi2 = 5.011$, $P < 0.05$) of the hospitals. Segregation of wastes and pre-treatment of infectious wastes were not properly practiced, and single chamber incinerators was the most utilized treatment method indicating poor management of the HCW. The study establishes that the little attention is given to medical waste management which primarily proceeds from a lack of due implementation of the national healthcare wastes management guideline/directive at the healthcare facility level. If the poor healthcare solid waste management is not properly addressed at the study hospitals, human (healthcare workers, waste handlers, patients, and nearby community) and environmental health risk will be within the bounds of possibility.

INTRODUCTION

Healthcare activities are means of protecting health, curing patients, and saving lives (Debere *et al*., 2013). Hospitals are among the complex institutions which generate a broad range of hazardous waste materials in the course of healthcare activities (Farzadkia *et al*., 2009). Healthcare waste is a major problem in most developing countries of the world due to its growing and endless

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generation coupled with poor management (Abd El-Salam, 2010). Healthcare waste contains a large component (75–90%) of non-risk or general healthcare waste, comparable to Municipal Solid Waste (MSW) and a smaller component (10–25%) of hazardous waste may pose a variety of health risks (WHO, 2014).

The process of collecting, storing, transporting, treating and disposing waste material is known as waste management (Al-Khatib and Sato, 2009). Improper waste management in which the infectious waste is mixed with the general waste can lead to the entire bulk of the wastes becoming potentially infectious. It is well known that inappropriate hospital waste management is pressing both health hazards and environmental pollution, facing many healthcare centers of this developing world (Bdour *et al*., 2007). Diseases like Cholera, Dysentery, Skin Infection, and Infectious Hepatitis can spread epidemic way due to the mismanagement of hospital solid waste (Coker *et al*., 2009). Therefore, it is urgent to determine appropriate methods for the safe management of hospital solid waste.

Uncontrolled combustion of medical waste accounted for 26% of the annual total Dioxins / Furans release in 2003 in Ethiopia (EEPA, 2006). Recently, considerable gap exists with regard to the assessment of healthcare solid waste management practices in Ethiopia. Unfortunately, relevant information on this important aspect of healthcare management is inadequate and research on the public health implications of inadequate management of healthcare solid wastes are few in number and limited in scope (Habtetsion *et al*., 2009). Ethiopia is signatory to the Stockholm Convention on Persistent Organic Pollutants (POPs), which is a global convention with the aim of eliminating some of the most long-lived anthropogenic pollutants (UNEP, 2009). While studies illustrate the solid waste menace in the Ethiopian towns and cities, the data on health care solid waste remains in huge paucity both at regional and national level. The present study, therefore, attempted to determine the healthcare solid waste composition, generation rate as well as evaluate its management systems in two selected hospitals of Shashemene town, Oromia region

MATERIALS AND METHODS

Description of the Study Area

Shashemene town is the capital of Shashemene Woreda (District) in West Arsi Zone of Oromia Regional state, Ethiopia. It lies on the Trans-African highway of Cairo-Cape Town, about 250 km from the capital of Addis Ababa. The town is located at Latitude of 7° 12' North and a Longitude of 38° 36' East. In Shashemene Woreda, there are Teaching and Referral (Shashemene Referral Hospital), and Private (Feya General Hospital) Hospitals providing services for more than 122,046 people. Shashemene Referral Hospital has a total of 240 beds with an average patient's flow of 282 patients/day providing Cafeteria, Emergency, General Medicine, Family Planning, Laboratory, Leprosy, TB and Malnutrition, Epilepsy and Psychiatry, Ophthalmic, Pediatrics, Surgical, Pharmacy, and Inpatient Services. Feya General Hospital is private owned hospital and the hospital is engaged in providing diagnostic and medical treatment in addition to providing other routine services, such as Out-Patient, Laboratory Services, Pharmacy Services, Emergency, Delivery, Family Planning, and Voluntary Counseling and Testing services etc. The Feya General Hospital accommodates a total of 150 beds with average patients/flow of 98 patients/day.

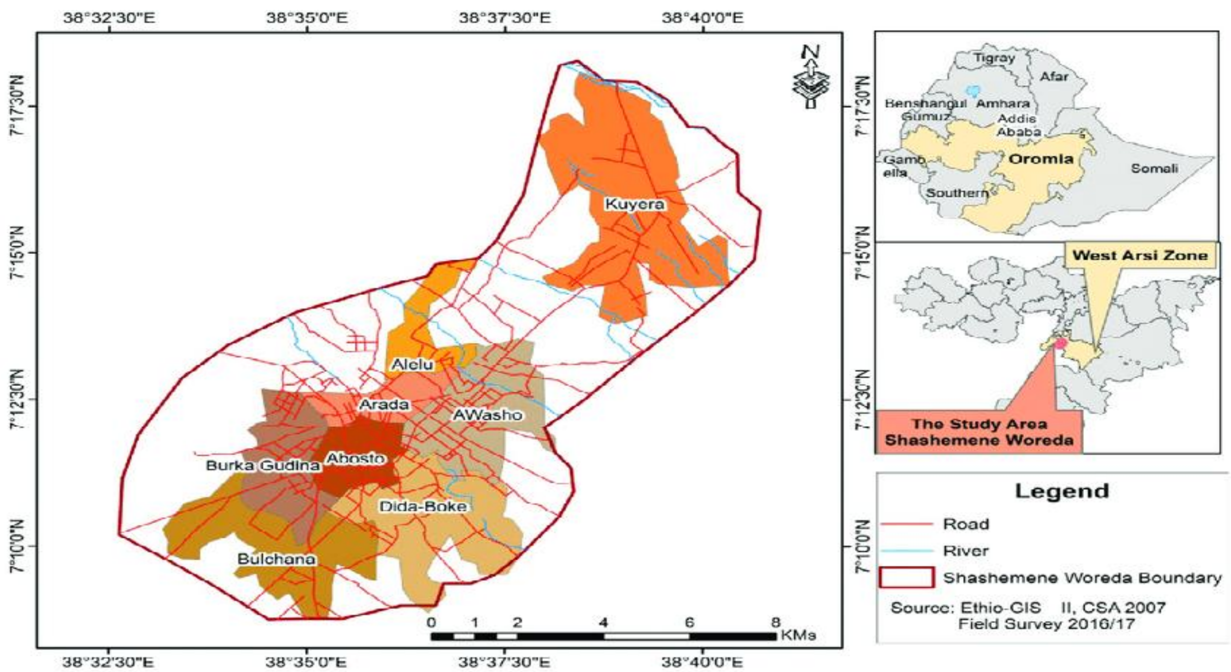

Figure. 1 Geographical map of Ethiopia and Oromia region showing map of the study area (Shashemene town)

The Study Design

It entailed a hospital-based cross-sectional study to evaluate the waste generation rate and its management system in the two hospitals of Shashemene town. The study was conducted in three phases (3 weeks of study). During the first week, a trial collection exercise was conducted before initiation of the regular collection program. The purpose of the first phase (i.e., first week of the study) was to identify the main waste types and characteristics, learn the skills of determining the respective quantities generated from the different departments/Case Teams and plan the daily collection and segregation of waste during the study period. The center of the 2nd phase of study was the management of hospital solid waste while the nub of the 3rd phase was determining the amount of waste generated. In the latter two phases (phase 2 and 3), waste collection and measurement took place for seven consecutive working days. The proposed indicator for the evaluation of hospitals waste management was a daily generated amount of healthcare waste to one bed (general waste per bed per day and hazardous waste per bed per day).

Determination of Sample Size

A stratified random sampling method was used to select the required categories of health professionals. A random sample is one in which every element in the population has an equal and independent chance of being selected from the sample (Crowther and Lancaster, 2009). The total population size (N) of the two Hospitals was 130, which comprise 75 nursing staffs, 33 medical staffs, and 22 other health and support staffs. This was pooled from government hospital (with 18 medical staff, 50 nursing staff and 12 other health staff) and private hospital (15 medical staff, 25 nursing staffs and 10 other health staff).

The sample size (n) was determined using the Slovin Formula $\frac{N}{1+NE^2}$

where n = Number of samples, N = Total population and E = Error tolerance (level).

Accordingly, the sample size required for the study was calculated to be 98respondents from both hospitals. When fractionated based on proportional allocation, the sample size is constituted of 25medical staffs (15 from Government, and 10 from Private), 56 nursing staffs (35 from Government, and 21 from Private), and 17other health staffs (10 from Private), and 7 from Private).

Data Collection

The method adopted for this study follows the procedure used by Longe and Williams (2006). Accordingly, data collection tools involved questionnaire survey, site visitation (personal observation) and Key Informant Interview. The key informants were purposively selected and includes heath care directors, experts and policy developers in the zone. Both the key informant interview and the Direct Observations were conducted by principal investigators while the questionnaires were administered subsequent to the translation (from English) to the local language of the study area (Afan Oromo). The site visit was conducted by using checklist to review the segregation, handling, collection and storage practices at the various case teams of the study hospitals.

Plastic polyethylene bags and labeled color coded waste containers were used for collection of solid waste from ward, laboratory and departments of the hospitals. The solid waste was manually separated (following appropriate safety precautions) into two categories such as Hazardous and Non-Hazardous as designated in WHO guideline (WHO, 1999). Electronic balance, calculator and recording forms were used for solid waste measurement and recording. Waste generation per day was determined by taking the fraction of the Total Waste produced over the study duration by the length of the study period (7 days) in kg day^{-1}. The solid waste generation can be computed by dividing the total weight of waste (in kg) generated per day with the number of beds in the hospital (i.e., the vacant beds were not considered) expressed as kg/bed/day or dividing the total weight of waste (in kg) generated per day with number of inpatients attended daily in the hospital expressed as kg/patient/day (Kagonji and Manyele, 2011). Likewise, Alagha *et al.* (2018) stated that a universal indicator of Medical Waste (MW) generation is the weight of Healthcare Waste generated per bed per day (kg bed^{-1} day^{-1}) for a given medical facility. Accordingly, waste generation per (occupied) bed per day was calculated as given below:

W_{bd} = [MW weight (kg)]/[(day) × (Bed)] where W_{bd}, is defined as the total weight of MW (in kg) generated per occupied bed per day.

Data Analysis

The data was entered into spread sheet of Microsoft Excel and exported to Statistical Package for Social Sciences (SPSS version 20) for analysis. For testing the Bi-Variate association between Hazardous Waste generated, Patient Flow, and Occupied Beds in study Hospitals, Spearman's Rank Correlation (rs) was computed following Gerald *et al*. (2004). Healthcare Waste (HCW) generation rate and categories of HCW among the different Case Teams in each Hospital were compared using Kruskal-Wallis-test as indicated in Gerald *et al*. (2004). Data from Key Informant Interviews and Direct Observation were analyzed by theme and the content analysis was made manually, by sorting the organized information according to thematic similarities and differences. P-value and rs was reported to present the extent of strength in terms of significant variation and association between two variables, in that order. In all the analysis, level of significance was set at $P< 0.05$.

RESULTS AND DISCUSSION

Healthcare Solid Waste Management Practice

Healthcare Solid Waste Segregation

In general, there is poor segregation of hazardous solid wastes even though the hospitals employ separate receptacles/bins. Besides, as reported by Katusiime (2018), Non-Hazardous Wastes (NHWs)/General Wastes (GWs) were often mixed with infectious wastes in the Government Hospital (GH). Notwithstanding this, both hospitals employed specific/separate bins for the collection of infectious wastes, and sharp wastes were collected in puncture proof safety boxes. Conversely, the hospital solid waste segregation practiced in Private Hospital (PH) was relatively better than the same for the GH. In similar vein, lack of proper HCW segregation in Ethiopia was reported by Tesfahun (2015), Hayleeyesus and Cherinet (2016), Meleko and Adane (2018), and Yazie *et al*. (2019). In Urban Referral Hospital in Uganda, Katusiime (2018) also reported that though waste was generally discarded in large waste bins and sharps in separate sharps containers, the notion of waste segregation was non-existent. On the other hand, as with Tesfahun (2015), the reuse and recycling practice of the NHWs were almost absent in both hospitals; in the GH, however, it was observed that there was some reuse of drug containers (e.g., cans, plastic and bottles) without any precautions. Similarly, Meleko and Adane (2018) found that there were no any observed activities performed by health professionals or other staff to reuse or recycle materials.

In the PH, healthcare solid wastes were merely segregated into infectious, sharps and pathological wastes whereas in GH the segregation was almost absent except the segregation of sharp waste using the safety box. On the other hand, placentas and blood stained cotton pads were kept in separate containers in PH. In the GH, in contrast, anatomical wastes are collected with wound dressings, placentas and blood/fluid-stained pads in a receptacle outside the wards (Figure. 2d). On the other hand, the use of waste containers with a color code and labelling at the point of generation was implemented in both hospitals. However, it was observed in GH that some receptacles with different color-codes were observed and, hence a color code-label mismatch was practiced (e.g., Blue and Green plastic bins were employed for Infectious Wastes and Non-Infectious Wastes, respectively) (Figure. 3). Yazie *et al*. (2019) in their review of studies conducted on Ethiopian Hospitals indicated that there was no use of proper color-coded bins for waste segregation. This may result in hazardous wastes not only being disposed inappropriately, but also with members of the community gaining access to such wastes. Similar non-compliance had been reported in primary healthcare centers assessments conducted in several developing countries such as Laos, Turkey, Mongolia, among others (Yong *et al*., 2009; Sanida *et al*., 2010). Consequently, as to Katusiime (2018), this will inevitably increase health risks to health workers, waste disposal workers, and the public. generation.

Figure 2. Waste collection and storage systems near the beds (a and b), in corridors (c), outside wards (d) in the Government Hospital, Shashemene, Ethiopia

Figure 3. Cases where there were Color Code–Label Mismatches in the Government Hospital

On the other hand, only 25% of the respondents from GH acknowledged that the wastes were segregated at the point of generation while 50% of the study participants from PH expressed recognition of the practice of segregation at the place of generation

(Table 1). Waste is segregated depending on the quantity, composition, and the disposal method of the waste stream (Shareefdeen, 2012). The present finding was similar with a finding obtained in Addis Ababa (Ethiopia) where almost all of assessed hospitals reported that there was no segregation of wastes and, had no separate bins for the collection infectious waste (Debere *et al*., 2013). As to WHO (2014), segregation of solid wastes should be performed by the producer of the waste as close as possible to its place of generation.

(a) (b) (c) (d)

Figure 4. Waste collection and storage systems near the beds (a and b), outside the bed rooms (i.e., in corridors) (c), outside the wards (d) in the Private Hospital, Shashemene, Ethiopia

Healthcare Solid Waste Collection, Interim-Storage and Transport

The arrangements of hospital solid waste collections and storages adjacent to the bed, in the corridor, and outside the wards are presented in Figures 2 and 4. In GH, solid waste generated was usually deposited into the small open plastic bins and open drug cartons close to the bedside, which ultimately produce unhygienic condition near the bed (Figures 2a and b). Conversely, in PH, the solid waste generated in similar location is collected in partially closed receptacles/bins placed away from each bed (Figure 4a and b).

All wards of the GH use substandard dustbins storages, such as trash bags, plastic buckets and drug cartons (that can be easily damaged) to store HCW temporarily in open for about 12–24 hours (Figure 2). In Government Hospitals, Tayework (2016) reported that all hospital solid wastes were temporarily stored in open and substandard dust bins for about unlimited time. The data presented in Table 1 shows that 75% of the respondents from GH indicated that the wastes were collected once per day. Conversely, in PH, colored plastic bins were placed in the designated place (Figure 4a) in each room while leak-proof containers made from stainless steel were placed outside the rooms (Figure 4d). Besides, in PH, healthcare waste was collected on daily basis by cleaning personnel and transported to the on-site handling area. As to the information displayed in the Table 1, 40% and 60% of the respondents from PH laid out that the wastes were collected once and twice a day, in that order. In all studied healthcare facilities, Hayleeyesus and Cherinet (2016) reported that HCW is collected on a daily basis by cleaning personnel and transported to an on-site handling area. On the other hand, in both hospitals, only Pathological and Sharp Wastes were collected, stored and transported in closed plastic buckets/containers within an hour. On the contrary to other Hazardous Wastes (HWs) like potentially infectious and sharp wastes were collected in puncture-proof containers (Safety Boxes) in both hospitals (Figures 2 and 3a). As to WHO (2014), collection times should be fixed and appropriate to the quantity of waste produced in each area of the healthcare facility and recommends that collection should be carried out daily for most wastes, with collection timed to match the pattern of waste generation during the day.

Table 1. Participants' response on the waste collection, treatment and disposal practices at the surveyed hospitals

Question	Response	Hospital	
		Government	Private
Do you segregate waste at the point of generation?	Yes	3(25%)	5(50%)
	No	7(58.3%)	4(40%)
	I don't know	2(16.7%)	1(10%)
Do you use gloves, boots, masks & caps when handling HCW?	Yes	3(25%)	4(40%)
	No	9(75%)	6(60%)
On-site handling (patient's bed to storage place)	Once per day	7(58.3%)	5(50%)
	Twice per day	1(8.4%)	3(30%)
	Irregular	4(33.3%)	2(20%)
On-site handling (storage place to final disposal)	Once per day	9(75%)	4(40%)
	Twice per day	1(8.3%)	6(60%)
	Irregular	2(16.7%)	0(0%)
Bags were filled with more than ¾ (75%)	Yes	7(58.3%)	6(60%)
	No	3(25%)	4(40%)
	I don't know	2(16.7%)	0(0%)
The filled bags were closed tightly before transferred	Yes	6(50%)	5(50%)
	No	2(16.7%)	2(20%)
	I don't know	4(33.3%)	3(30%)
The filled bags were replaced with empty one at the same time of discharge	Yes	5(41.7%)	7(70%)
	No	7(58.3%)	3(30%)
Vessel used for the transport of a sharp waste was perforated	Yes	8(66.7%)	2(20%)
	No	4(33.3%)	8(80%)
Waste treatment method used	Incineration	9(75%)	6(60%)
	Open burning	2(16.7%)	2(20%)
	Burial	1(8.3%)	2(20%)
Do you treat hazardous HCW differently from general waste?	Yes	5(41.7%)	7(70%)
	No	3(25%)	2(20%)
	I don't know	4(33.3%)	1(10%)

From PH and GH involved in the present study, only 40% and 25% of the respondents, respectively, indicated that waste bags and sharp containers were filled to ¾ full (Table 1). Waste bags and sharps containers should be filled to no more than three quarters full and once this level is reached, they should be sealed ready for collection (WHO, 2014). On the other hand, 70% and 41.7% of the participants from PH and GH, respectively, made known that the filled bags were replaced with empty one during waste collection (Table 1). Replacement bags or containers should be obtainable at each waste-collection location so that full ones can immediately be replaced (WHO, 2014).

As with Tesfahun (2015), Tayework (2016) and Meleko and Adane (2018), both hospitals lack of proper and purpose-built waste storage rooms; however, there was a temporary waste storage room for pharmaceutical wastes in the PH. Conversely, similar to the findings reported by Meleko and Adane (2018), both hospitals employ interim waste storage (plastic bucket) outside the wards; wastes were stored for 24–36 and 12–24 hours in the GH (Figure 2d) and PH (Figure 4d) Hospitals, respectively. Debere *et al*. (2013) observed that hospital solid wastes were stored in temporary storage area from 2 weeks up to one month before final disposal.

On the other hand, in both hospitals, the Janitors handle the HWs without wearing Personal Protective Equipment (PPE) and empty (discard) the smaller containers into the larger ones which are placed in the corridors and outside the door. Accordingly, 75% and 60% of the respondents from GH and PH, in that order, revealed that the waste handlers did not employ PPE while managing of the wastes. In a similar study by Meleko and Adane (2018), only about 24% of the waste collectors/waste handlers had worn glove and boots during waste collection and transportation of healthcare wastes. In their study on the East and West Kumbo health districts of Cameroon, Dzekashu *et al*. (2017) found that the use of PPE like Gloves (100%) were the most common practice by waste handlers, followed by Aprons (85.2%) and Boots (55.6%).

In GH, HWs and NHWs were mixed outside each room (Figure 2d), and transported to incineration area using wheeled trolleys/handcart (Figure 5a), waste bags (carrying the same by their hands, on their shoulders, or using pushcarts) (Figures 5a and b). Although the transport of HCWs in the PH was comparatively better and principally involved wheeled trolleys/carts (Figure. 5c and d), the same appeared not to be appropriately sized according to the volumes of waste generated at a health-care facility. Moreover, during the transport of the solid wastes from the interim storage receptacles to the treatment area within the hospital premises could entail the possibility of infectious waste droppings on the walkways (Figure 5). Awodele *et al*. (2016) indicated that wheel barrows and trolleys comprised the major means of evacuating the waste whereas Dzekashu *et al*. (2017) observed that transportation of medical waste was virtually (96.7%) executed by lifting, and only 3.3% of the health facilities employed trolleys for transporting wastes.0.05).

Figure 5. Healthcare solid waste transport in the Government (a, b) and Private (c, d) Hospitals

Healthcare Solid Waste Treatment and Disposal Practice

In both hospitals, waste storage and transporting plastic buckets were not treated with disinfectants as suggested by WHO (2014). Besides, as with Tesfahun (2015), none of the hospitals practiced pre-treatment of highly infectious waste. However, the Laboratory Department of the PH treated infectious waste (including Cultures and Stocks, Sharps, materials contaminated with Blood, etc.) by autoclave machine. Conversely, 41.7% and 70% of the respondents from GH and PH, respectively, maintained the belief that HWs should be treated differently from GWs (Table 1). The existing methods employed to treat solid wastes by both hospitals, in their order of importance, were Incineration (brick-made to burn sharp wastes), Open Burning, and Burial (Table 1). As a rule, the choice of treatment system involves consideration of waste characteristics, technology capabilities and requirements, environmental and safety factors, and costs – many of which depend on local conditions (WHO, 2014).

In GH, there was construction of new incinerator for treatment at the time of study because the former one became out of use due to unavailability of gas connection, old and filled with ash (Figure 6a). Consequently, the partially burned healthcare solid waste was further burnt and disposed of in an open pit within the GH (Figure 6b and c). In the PH, conversely, the incinerator was not only properly functioning as depicted by incomplete burning of waste (Figure 7a and b), but also was located close by the residential area of the medical staff within the hospital premises. Consequently, apart from failure to significantly reduce the volume of treated waste, incinerators of both hospitals generated a plume of smoke to their immediate environments. The use of low combustion single-chamber incinerators for the treatment of healthcare waste was against the Stockholm Convection on Persistent Organic Pollutants (POPs) (UNEP, 2009) since such incinerators release air pollutants to the environment (Diaz *et al*., 2005).

On the other hand, both hospitals had an open hand dug pit in their backyard that was used for the open burning and direct dumping of GWs. While the GH had an open placental pit for disposal of pathological and anatomical waste generated from the delivery and operation rooms (Figure. 6d), the PH employed one closed placental pit (Figure. 7c) and two closed ash pits. As with the case reported by Meleko and Adane (2018), HCWs in both hospitals were not disposed of in appropriate sealed and labeled containers. Such malpractices were also reported in Jos Metropolis, Nigeria (Ndidi *et al*., 2009). Generally, each component of HCW management practices in both surveyed hospitals did not conform to the Ethiopian National Healthcare Waste Management Guideline. Such poor HCW management were also reported in similar studies conducted in Nigeria (Di Bella *et al*., 2012), South Africa (Nemathaga *et al*., 2008), and Iran (De Titto *et al*., 2012).

Figure 6. Solid waste treatment methods: (a) Incineration, (b and c) open burning at waste dump site and (d) Anatomical, Pathological and Placental burial pits in the Government Hospital of Shashemene town.

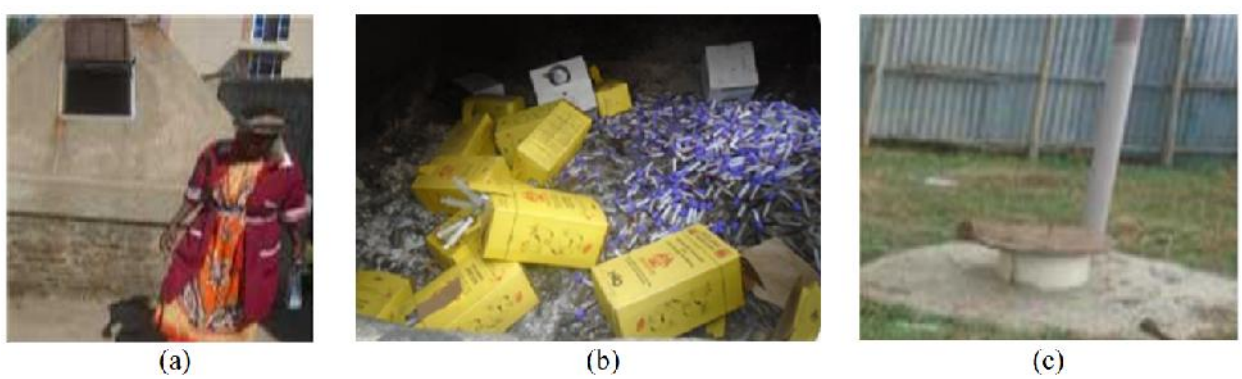

Figure 7. Solid waste treatment methods: Incineration (a and b), and (c) Anatomical, Pathological and Placental pit employed in the Private Hospital

Waste Generation and Characterization

The total weight of HCW generated in GH and PH in Shashemene town were 316.5 kgweek^{-1} and 140 kg week^{-1}, respectively. Conversely, an average total of 45.2 ± 5.8kgday^{-1}(0.20kg bed^{-1}day^{-1}) of HCW was generated from GH whereas only below half as much (20 ± 2.4kg day^{-1} or 0.19kg bed^{-1}day^{-1}) of the same was produced from PH (Tables 2, 3, and 4). Although the above generation rate was somehow comparable to 0.164 kg bed^{-1}day^{-1} reported by Meleko and Adane (2018), the same was lower than a result obtained in Ethiopia (1.5kgbed^{-1}day^{-1}: Tesfahun, 2015), Bangladesh (1.24kgbed^{-1}day^{-1}: Hassan *et al*., 2008), Egypt (1.03kgbed^{-1}day^{-1}: Shouman *et al*., 2013) and France (3.3kgbed^{-1}day^{-1}: Windfeld and Brooks, 2015). Variations in waste generation hinges on the type or level of healthcare facility (WHO, 1999; Bdour *et al*., 2007; Haylamicheal et al., 2011; WHO, 2014), hospital specializations (WHO, 1999), location (Rural or Urban) (WHO, 2014), established waste management methods, proportion of reusable items employed in healthcare facilities (WHO, 1999; Bdour *et al*., 2007; Haylamicheal *et al*., 2011), level of activity (number of occupied beds, number of patients per day, and/or number of staff), type of department, temporal variations (e.g. weekday versus weekend, seasonal), and level of infrastructure development of the country (Bdour *et al*., 2007; Haylamicheal *et al*., 2011; WHO, 2014).

Table 2. Distribution and healthcare solid waste generation rates by point source and type in Government Hospital of Shashemene

Government Hospital	**Non-Hazardous Waste (Kg week^{-1})**	**Hazardous Waste (Kg week^{-1})**				**Total Hospital Waste (Kg Week^{-1})**	**Percentage of Total Hospital Waste (%)**	**Average Daily Hospital Waste (Kg Day^{-1})**
		IW	**PhW**	**SW***	**PaW**			
OPD	30.3	5.9	14	0.6	7.0	57.8	18	8.3
Surgical	27.9	4.7	3.9	1.5	-	38	12	5.4
Pediatrics	20.4	7.3	3.5	4.7	8.1	44	14	6.3
Obs/Gyn.	16.5	9	9	5.2	10.2	49.9	16	7.1
Medical	27.6	10.5	2.4	1.6	3.1	45.2	14	6.5
Laboratory	15.9	5.5	8.9	2.7	9.1	42.1	13	6.0
Emergency	30	4.2	-	3.2	2.1	39.5	13	5.7
Total (Kg week^{-1})	***168***	***47.1***	***41.7***	***19.5***	***39.6***	***316.5***	***100***	**45.2 ± 5.8**
Mean ± SD (Kg Day^{-1})	**24.1 ± 6.3**	**6.7 ± 2.3**	**6.0 ± 4.8**	**2.8 ± 1.7**	**5.7 ± 3.9**	**45.2 ± 5.8**	**-**	
% wt. by Type	53.3	14.8	13.2	6.2	12.5	100	-	

IW = Infectious Waste; PhW: Pharmaceutical Waste; SW: Sharp Waste; PaW: Pathological Waste
**Includes Needles, Blades, Lancet Needles, Syringes, and Scalpel Blades*

Of the total waste generated in GH, 53.3% (24.1 ± 6.3 kg day^{-1} or 0.1 kg bed^{-1}day^{-1}) was GW while 46.7% (21.1 ±3.2 kg day^{-1} or 0.091kg bed^{-1}day^{-1}) was HW (Tables 2 and 4). Equally, of the total waste generated in PH, 57.1% (11.4 ± 2 kg day^{-1} or 0.11 kg bed^{-1}day^{-1}) was GW whereas 42.9% (8.6 ± 1.3 kg day^{-1} or 0.079 kg bed^{-1}day^{-1}) was HW (Tables 3 and 4). A little over half of the total HCW generated from the study hospitals (GH:

53.3%; PH: 57.1%) constituted GW. Meleko and Adane (2018) reported that 0.091 kg /bed/ day (55.5%) was GW and the remaining 0.073 kg/bed/day (44.5%) was HW. Likewise, in similar studies conducted in Ethiopia, Azage and Kumie (2010), Debere *et al*. (2013), and Hayleeyesus and Cherinete (2016) the GW accounted for the 52, 58.69, and 65.1% of the total HCW. Moreover, the result of the present study is comparable with a results obtained from healthcare facilities in Ethiopia where 48% (Azage and Kumie, 2010), 41.31% (Debere *et al*., 2013), and 42.1% (Meleko and Adane, 2018) of HCW were HW. Conversely, the present finding was much bigger than a result identified in Sudan where only 20% of the total HCW generated was HW (Ahmed *et al*., 2014).

On the other hand, between 75% and 90%of the waste produced by health-care providers are actually NHWs or GWs, and the remaining 10–25% is HWs in nature (WHO, 2014). It is apparent that the proportions accounted by HWs from the present study were higher than the same reported by the WHO (2014). Yazie *et al*. (2019) pointed out that the fractions of HW generated from healthcare facilities were intolerably high with a range stretching from 21–70% of the total solid waste. As indicated by Hayleeyesus and Cherinete (2016), the higher proportion of HWs in the present study (as well as in most healthcare facilities in Ethiopia) could be ascribed to the lack of segregation of waste at the point of generation. In a study done on private and government hospitals, Debere *et al*. (2013) found that the HW and non-HWs were mixed in the hospital's temporary storage areas.

Table 3. Distribution and healthcare solid waste generation rates by point source and type in Private Hospital of Shashemene

Private Hospital	**Non-Hazardous Waste (Kg week^{-1})**	**Hazardous Waste (Kg week^{-1})**				**Total Hospital Waste (Kg Week^{-1})**	**Percentage of Total Hospital Waste (%)**	**Average Daily Hospital Waste (Kg Day^{-1})**
		IW	**PhW**	**SW ***	**PaW**			
OPD	11.5	0.5	4.1	1.5	3.0	20.6	14	2.9
Surgical	12.1	2.3	2.5	2.5	2.2	21.6	15	3.1
Pediatrics	13.3	3.1	2.4	0.8	3.2	22.8	17	3.3
Obstetrics/Gyn.	11.9	2.0	0.7	1.6	4.1	20.3	15	2.9
Medical	8.2	1.9	4.2	2.2	1.5	18	13	2.6
Laboratory	9.4	4.3	-	2.0	-	15.7	11	2.2
Emergency	13.6	1.2	4.6	0.4	1.2	21	15	3.0
Total (Kg week^{-1})	***80***	***15.3***	***18.5***	***11***	***15.2***	***140***	***100***	**20 ± 2.4**
Mean ± SD (Kg day^{-1})	**11.4 ± 2.0**	**2.2 ± 1.2**	**2.6 ± 1.8**	**1.6 ± 0.8**	**2.2 ± 1.4**	**20 ± 2.4**	**-**	
% wt. by Type	57.1	10.9	13.2	7.9	10.9	100	-	

IW = Infectious Waste; PhW: Pharmaceutical Waste; SW: Sharp Waste; PaW: Pathological Waste
**Includes Needles, Blades, Lancet Needles, Syringes, and Scalpel Blades.*

The types of hazardous wastes generated from the study hospitals were infectious, pharmaceutical, pathological, and sharps. In both hospitals, the infectious [GH: 14.8%; PH: 10.9%] and pharmaceutical [GH: 13.2%; PH: 13.2%] wastes dominate the HWs category while sharp wastes [GH: 6.2%; PH: 7.9%] contribute for the lowest fractions to the total as well as to the selfsame category in either hospital (Tables 2 and 3). In a similar vein, Hayleeyesus and Cherinete (2016) found that infectious waste (21.1% of the total HCW) dominated the HW fraction while the sharp waste contributed the least (1.5%) to the total solid waste from the healthcare facilities.

Table 4. Average daily healthcare solid waste generation by types of wastes in Shashemene hospitals

Types of Waste	**Type of Hospital**			
	Government		**Private**	
	Kg Day^{-1}	**Kg Bed^{-1} Day^{-1}**	**Kg Day^{-1}**	**Kg Bed^{-1} Day^{-1}**
General Waste	24.1	0.1	11.4	0.11
Infectious Waste	6.7	0.03	2.2	0.02
Pharmaceuticals	5.9	0.025	2.6	0.024
Sharps	2.8	0.012	1.6	0.015
Pathological Wastes	5.7	0.024	2.2	0.02
Total HCSW	**45.2**	**0.20**	**20**	**0.19**

HCSW stands for Healthcare Solid Waste

In the GH (Table 2) the highest percentage of the total HCW was generated from OPD (18%) followed by Obstetrics/Gynecology (16%) while the lowest proportion of total waste was generated from Surgical Ward (12%). On the other hand, the Pediatric Ward (17%) followed by Obstetrics/Gynecology, Emergency, and Surgical wards (15% each) contributed for the highest fractions of total waste generated from PH whereas the waste proceeding from the Laboratory (11%) was the lowest proportion of the total HCW (Table 3). Meleko and Adane (2018) reported that the largest portions of total waste were contributed by Gynecological Ward followed by Medical Ward while the lowest proportion was generated in Office.

As to the data presented in Table 5, there were significant differences in the different wards of the Government Hospital with respect to general waste (χ^2 = 31; P <0.001), hazardous waste (χ^2 = 25; P <0.001), and total healthcare waste (χ^2 = 46; P <0.01). Likewise, significant variations were observed in the Private Hospital wards regarding the general waste (χ^2= 13; P <0.01), hazardous waste (χ^2 = 10; P <0.01), and total healthcare waste (χ^2 = 22; P <0.01). Similarly, Meleko and Adane (2018) reported that there were significant variations among the different wards in relation to general waste (χ2=41.815;P< 0.01), hazardous waste (χ2=44.324;P<0.01), and total healthcare waste (χ2 = 44.604;P< 0.01).

Table 5. Comparison of mean generation rate of healthcare solid waste and categories of HCSW by departments within the government and private hospitals using Kruskal Wallis H test

Wards	Type of Hospital					
	Government			Private		
	GW	HW	THCW	GW	HW	THCW
OPD	30.3	27.5	57.8	11.5	9.1	20.6
Surgical	27.9	10.1	38	12.1	9.5	21.6
Pediatrics	20.4	23.6	44	13.3	9.5	22.8
Obs/Gyn.	16.5	33.4	49.9	11.9	8.4	20.3
Medical	27.6	17.6	45.2	8.2	9.8	18
Laboratory	15.9	26.2	42.1	9.4	6.3	15.7
Emergency	30	9.5	39.5	13.6	7.4	21
Chi-Square	31	25	46	13	10	22
P-Value	0.0001	0.0001	0.001	0.001	0.001	0.001

GW: General waste; HCW: Healthcare Waste; HW: Hazardous Waste; Obs/Gyn: Obstetrics/Gynecology; OPD: Outpatient Department

According to Table 6, there were significant differences between the mean total HCW ($\chi2$ = 9.016;P< 0.01), general waste ($\chi2$ = 9.8;P< 0.01) and the hazardous waste ($\chi2$ = 5.011;P< 0.05) of the study hospitals. Similar to the findings of the present study, Debere *et al*. (2013) reported that there was statistically significant difference for total amount of HCW ($\chi2$ = 30.65;P< 0.001),HW ($\chi2$ = 20.431;P < 0.01) and NHW ($\chi2$ = 29.011;P< 0.001) among the surveyed hospitals.

Table 6. Comparison of healthcare waste generation rates and categories of HCW using Kruskal-Wallis test among the surveyed hospitals

Type of Hospital	Mean Rank		
	Total HCW*	GW**	HW***
Government	10.86	11.00	10.00
Private	4.14	4.00	5.00
Chi-square	9.016	9.800	5.011
P- Value	0.003	0.002	0.025

** Healthcare Waste, ** General Waste, *** Hazardous Waste*

The Spearman's rank correlation coefficient (r_s) (Table 7) showed that there was a positive linear relationship between number of patients and quantities of hazardous waste generation rates in both PH (r = 0.954, P< 0.05) and GH (r = 0.847, P< 0.01). Similarly, there was positive correlation coefficients among HW generation rates and occupied beds in both PH (r = 0.964, P< 0.05) and GH (r = 0.821, P< 0.001) (Table 7). Moreover, positive associations were observed between patient flow and occupied beds in PH (r = 0.991, P< 0.01) and GH (r = 0.955, P< 0.05). In their study on HCWs, Tadesse and Kumie (2014) found that there was a positive linear relationship between number of patients and the HCWs generated in all government facilities studied. Conversely, Issam *et al*. (2009), Haylamicheal *et al*. (2011), and Komilis *et al*. (2011) reported that there was a positive correlation between the total HCW generation rates and the number of beds.

Table 7. Spearman's Correlation Matrix (r_s) between Hazardous Wastes (HW) generated, Patient Flow and Occupied Beds in Private and Government Hospitals

Government Hospital		HW	Patient Flow	Occupied Beds
Spearman's rho	HW	1.00	0.954**	0.964***
	Patient Flow		1.00	0.955**
	Occupied Beds			1.00
Private Hospital		HW	Patient Flow	Occupied Beds
Spearman's rho	HW	1.00	0.847*	0.821*
	Patient Flow		1.00	0.991**
	Occupied Beds			1.00

, **, and * represent $P < 0.05$, $P < 0.01$, and $P < 0.001$, in that order*

CONCLUSION

Although the HCW generations rates were relatively low, the standard HCW segregation was lacking in both hospitals. Consequently, except the sharp materials, all other HCWs were mixed with the GWs (mainly in GH), and hence, the proportion of HWs generated in the study hospitals surpassed the corresponding threshold measure indicated by the WHO. Besides, the waste collectors handle the HCWs without employing PPE, exposing themselves to potential health risk. Both hospitals principally treated HCW using low combustion single-chamber incinerators which could potentially contribute to the release of huge amounts of air pollutants to the environment.

As the HCW management in both hospitals was poor, sufficient resource allocation, periodic training, and strict supervision and proper implementation of HCW management is pivotal. Additionally, heath care facilities in Oromia region, should acquaint HCW management guideline for standardized waste categorization and safer handling. Besides, the key stakeholders of the region involving heath care directors, experts and policy developers should join hands in structuring the HCW management system in a way that appraises human and environmental health. For this, further researches need to be conducted in health care facilities of the region and the wider nation with consideration of human health risk assessment.

Ethical Consideration

Ethical clearance was obtained from Zonal Health Office whereas an approval to conduct the study was secured from the Managers/Directors of the respective Hospitals. The experimental procedures were explained to the individual participants and thereafter their consent to participate in the study was obtained. The participants were free either to participate or not. Besides, the right of respondents to interrupt or withdraw the interview when they deem it necessary was duly respected. Data collectors were trained touse protective materials when handling healthcare wastes. Privacy and confidentiality were assured by way of employing anonymity.

Conflicts of Interest

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

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