Biomedical waste management practices and associated factors among health care workers in the era of the covid-19 pandemic at metropolitan city private hospitals, Amhara region, Ethiopia, 2020

Getasew Mitiku1, Amha Admasie2, Amsalu Birara2*, Wubante Yalew3

1 Debretabor Health Science College, Debre Tabor, South Gondar, Ethiopia, 2 Department of Environmental Health, Bahir Dar University, School of Public Health, Bahir Dar, Ethiopia, 3 Public Health Researcher, Addis Ababa, Ethiopia

* amsalubirara@yahoo.com

Abstract

Background
Biomedical waste management is an important precondition to safeguard the healthcare workers and community members, as well as the environment, from being contaminated with infectious substances. However, biomedical waste management practices during the pandemic era of COVID-19 were unknown.

Objective
This study was aimed to assess biomedical waste management practices and associated factors among health care workers during the COVID-19 pandemic era at metropolitan city private hospitals, Amhara Region, Ethiopia.

Methods
An institutional-based cross-sectional study was conducted at metropolitan city private hospitals in Amhara Region. Simple random sampling was used to select 431 study participants. Data were collected through a self-administered questionnaire and observational checklists. The data were cleaned, coded, and entered into the Epi-data version 4.6, and then exported to SPSS version 20. for analysis. Variables with a p-value less than 0.05 were considered as significant factors in multivariable logistic regression analysis and AOR with a 95% confidence level was used to measure the strength of association.

Results
The proportion of health care workers who had good practices in biomedical waste management was 49.4%. Participants who had MSc education level, [AOR = 4.20, 95% CI (1.01, 17.40)], Bachelor degree [AOR = 3.52, 95% CI (2.13, 5.82)], got training on biomedical
waste management [AOR = 4.33, 95% CI (2.71, 6.93)], access to color-coded three bins in their working department [AOR = 6.24, 95% CI (3.84, 10.13)] and those who had good attitude (AOR = 2.64, 95% CI (1.65, 4.22), were significantly associated with biomedical waste management practices in private hospitals.

Conclusion

The practice of biomedical waste management in the study area was low. Level of education, taking training on biomedical waste management, availability of color-coded three bins, and attitude of health care workers were significantly associated with biomedical waste management practices. Hence, in-service training is recommended to improve biomedical waste management practices.

Introduction

Biomedical waste (BMW) is any waste that is generated during the diagnosis, treatment, or immunization of human beings or animals or from research activities, and contains potentially harmful microorganisms which will infect hospital communities and the general public [1,2].

BMW includes sharps, non-sharps, blood, body parts, chemicals, pharmaceuticals, medical devices, and radioactive materials [3]. Common sources of biomedical waste include hospitals, nursing homes, clinics, laboratories, offices of physicians, dental, and veterinarians, home health care, and funeral homes [4,5]. BMWs are considered because they represent the second hazardous waste globally after radiation waste [6].

Biomedical waste is a relevant problem for several countries and poses serious public health threats worldwide [7]. Nearly 3.2 million tons of biomedical waste is generated by hospitals alone annually and the Environmental Protection Agency (EPA.2019) estimates that 10% to 15% of all biomedical waste is potentially hazardous [8].

According to the World Health Organization (WHO), nearly 85% of waste generated by the hospitals is general waste and about 15% of waste is biomedical waste, composed of 10% of infectious wastes and 5% of non-infectious wastes like radioactive and chemical wastes [9]. In developing countries, especially in Africa, BMW has not received the attention it deserves [10].

Biomedical waste management (BMWM) is the process of segregation, collection, storage, treatment, transport and disposal, and other safety measures of waste in health institutions [11]. Proper BMWM includes vital steps, such as segregation, collection, storage, transportation, treatment, and final disposal, of waste generated in health care settings [12]. Improper BMWM, which includes hazardous wastes (10–25%) mixed with the non-hazardous waste (75–90%) can result in the whole bulk waste becoming potentially hazardous [13]. There are international agreements and Conventions which are particularly pertinent in BMWM, environment protection, and its sustainable development and thus they should be kept in mind by preparing waste management policies [14]. Adequate knowledge, attitude, and practice (KAP) of health care workers (HCWs) are key factors for having a successful BMWM system, as they are important preconditions to safeguard the community [15], and the environment from being contaminated with infectious substances [16].

In Ethiopia, public hospitals provide training associated with infection prevention and healthcare waste management to waste handlers, environmental professionals, and heads of departments, but there was no published evidence indicating that private hospitals provide any
training associated with healthcare waste management and infection prevention for health care workers [17].

In the Ethiopian context, there was no separate regulation specific for the HCFs to enforce them for the proper management of hazardous waste. However there are three BWM guidelines prepared by the Federal Ministry of Health (FMoH), Food, Medicine and Healthcare Administration and Control Authority (FMHACA), and Federal Environmental Protection Authority (FEPA) independently which are not, updated and lacked proper compliance on their implementation [18–21].

COVID-19 has been reported to first begin in December 2019 [22] while the WHO announced a Global Pandemic in March 2020. COVID-19 has been rapidly spreading all over the world, forcing countries and governments to adopt strict and specific measures to contain the pandemic. According to the Federal Ministry of Health of Ethiopia, the first COVID-19 case was reported in March 2020, and measures for tackling the pandemic have been taken ever since. In this regard, proper disposal of the waste is strongly relevant, as it may lead to the spread of communicable diseases [23]. Abundant use of medical technologies in hospitals and safety measures to stop the dissemination of the COVID-19 have led to a tremendous increase in BMW generation [24]. The generation rate was reported about 9200 tons/day of PW, with a total generation of more than 3.3 million tons per year in India [25], and The total mean weight of waste generation rate in the hospital was 492.5 kg/day in Ethiopia [26]. Moreover, the waste generated in health care facilities during the treatment and laboratory tests is highly contagious and hazardous [23].

According to the WHO 2018 report, the biomedical waste generation rate in low-income countries was 0.2kg of hazardous waste per hospital bed per day [27]. However, the Biomedical waste generation rates vary across different hospitals in Ethiopia where the generation rate ranges from (0.164–1.94) kg/bed/day, and (0.396–0.866) kg/bed day (0.92kg/bed/day and/or 0.75kg/) patient/day hazardous waste [28–31]. Health facilities in Ethiopia have chosen incineration to treat BMW [32,33], but 80% of hospital incinerators used low-temperature technology that generates air pollutants [34].

The BMW is often the source of over 30 dangerous blood-borne pathogens [35]. Worldwide, about 5.2 million people (including 4 million children) die each year due to exposure to BMW [36], The hazards of exposure to hospital waste can range from developing gastroenteritis, respiratory and skin infections, as well as more deadly diseases like Human Immunodeficiency Virus Acquired Immunodeficiency Syndrome (HIV/AIDS), and Hepatitis B (HBV); moreover, injections with contaminated syringes caused 21 million hepatitis B infections (32% of all new infections), 2 million hepatitis C (HCV) infections (40% of all new infections) and 260,000 HIV infections (5% of all new infections) [37,38].

In developing countries, the management of BMW is becoming a growing concern in urban areas [39]. However, Pathogens and toxic chemicals in BMW can pose serious health risks for waste collectors, patients, and health care workers. Among these risks, HIV/AIDS, HBV, and HCV can be mentioned. HIV, HCV, and HBV have the risk of transmission 0.3%, 1.8%, and 30%, respectively from one sharp injury [40].

Few studies conducted in Ethiopia indicated that lack of training, awareness, staff resistance, managerial poor commitment, lack of adequate resources, negligence, and unfavorable attitude of the healthcare staff were the main identified challenges of BMWM [21,28,41,42]. Therefore, assessing the practice of BWM and its associated factors among health care workers is a pivotal element to halting this burden. Accordingly, this study is planned to assess the practice of biomedical waste management and associated factors among health care workers in private hospitals of the metropolitan city of the Amhara region.
Methods

Study area
Amhara Region is found in Northwestern Ethiopia and has an estimated acreage of about 170000 square kilometers. The region borders Tigray within the North, Afar within the East, Oromiya within the South, Benishangul-Gumz within the Southwest, and also the country of Sudan to the West. The region has three metropolitan cities (Bahir Dar, Gondar, and Dessie). In line with the population size estimation of 2016, the total population was 1,937,081. (797,794 in Bahir Dar 740,859, in Gondar, and 398,428 in Dessie). In these metropolitan cities, there are eight private hospitals namely Gamby, Afelas, Dreamcare, Ethiogeneral, Batty, Selam, and Ibex with six hundred ninety healthcare workers.

Study design and period
An institutional-based cross-sectional study was carried out from November 25 to December 25/2020.

Population
The source and study population of the study were all health care workers who were working in private hospitals in metropolitan cities of the Amhara region (Bahir Dar, Dessie, and Gondar). The study unit was, randomly selected health care workers.

Inclusion and exclusion criteria
Health care workers in private hospitals who were employed 6 months or longer were included in the study, However, health care workers who were unable to communicate due to illness were not eligible for the study.

Sample size determination and sampling procedure
The sample size was determined using Epi-info version 7 considering (78.9%) biomedical waste management practice in Debre Markos Town Healthcare Facilities, Amhara region [43]; at 4% of the marginal error, 95% of confidence level (CL), and a 10% response rate. Therefore, the sample size was 440. Amhara Region has three metropolitan cities. All private hospitals in the metropolitan cities in the region were identified by name and included in the study. The sample size was allocated proportionally to each private hospital. Then simple random sampling was employed to select healthcare workers from each private.

Study variables
Biomedical waste management practice was our dependent variable. On the other side, socio-demographic characteristics of respondents, Healthcare facility-related factors, Knowledge of HCWs, and Attitude of HCWs were the independent variables of the study.

Data collection method and instruments
The data were collected using a self-administered questionnaire and observational checklist. The questionnaire was comprised of socio-demographic characteristics, knowledge, attitude, and healthcare facility-related factors. The questionnaire and observational checklist were first developed in English and then translated into Amharic, by English and Amharic language professionals to check its consistency. Data were collected by 5 trained clinical nurses and supervised by 3 trained BSC Environmental Health Professionals.
Quality control

The training was given to data collectors, and supervisors regarding the objective of the study, a basic skill of communication, how to conduct the self-administered questionnaire for one day. Before the actual data collection, pre-testing was conducted on 5% of the sample size at Debre Tabor Referral Hospital and the necessary correction was made based on the pre-testing findings. The completeness of the questionnaire was checked every day by the supervisors and principal investigator. These supervisors were available throughout the data collection period.

Data processing and analysis

Data were entered into Epi-data software version 4.6 and then exported to the SPSS software version 20 for analysis. Descriptive statistics were carried out to illustrate the means, standard deviations, and frequencies of the demographic profile, knowledge, attitude, and BMWM practice. Binary logistic regression analysis was made to identify variables having an association with the dependent variable. Then all independent variables with a p-value < 0.25 in the bivariable analysis were entered into multivariable logistic regressions to control the effect of confounding. Model fitness was checked using the Hosmer Lemeshow test. Finally, variables with a p-value less than 0.05 were considered as significant factors, and AOR with a 95% confidence level was used to measure the strength of association.

Ethical statement

Ethical clearance was obtained from the ethical review board of the college of medicine and health science, Bahir Dar University. Communication with different official administrators was done through a formal letter obtained from Bahir Dar University and the metropolitan cities health bureau. Before starting data collection, the participants had read the objective, benefits, and risks of the study to get informed verbal consent of participants. The right of the respondent to withdraw from the interview or not to participate was respected. To keep the confidentiality of any information provided by study participants, the data collection procedure was anonymous.

Operational definition of terms

Biomedical waste, medical waste, healthcare waste, and hospital waste are terms that have been used interchangeably [41]. However, healthcare waste has been more frequently used by published articles so far [44].

Biomedical waste management practice

The response to questions related to biomedical waste management practice was summed up and calculated the mean. The mean and above indicated good practice and the below mean indicated poor practice towards biomedical waste management practice [39].

Knowledge

The response of knowledge questions was summed up and a total score was computed with value and taken mean score. The mean and above indicated good knowledge and the below mean indicated poor knowledge towards biomedical waste management practice [43].

Attitude is a judgment of individual behavior as good or poor and was measured based on the 5 points Likert scale by summing the Likert questions. The mean and above indicated a good attitude and the bellow mean indicated a poor attitude towards biomedical waste management practice [43].
Health care workers
HCWs are people who are involved in the promotion, protection, and enhancement of population health. In this study, the term health care worker was standing for clinical staff and cleaners [43].

Result
Socio-demographic and healthcare-related characteristics
A total of 431 HCWs have participated in the study and the response rate was 98%. About, 245 (56.8%) were females. The mean age of the respondents was 29 years (with SD±4.68). Regarding educational status, 256 (59.4%) were first degree, and 12 (2.8%) were certificate and bellow. More than half, (52%) of the HCWs had more than 5 years of work experience. (Table 1).

Health care facility-related factors
Regarding training access, 201 (46.6%) of health care workers had taken BMWM training. About 388 (90%) workers were working 8 hours a day in different work environments such as 155 (36%) in OPD, 132 (30.6%) in Ward, and the rest in the laboratory, emergency, pharmacy, and others. In the working environment, only 223 (51.7%) of them had three bins for waste segregation. (Table 2)

As stated in Fig 1 below, among the studied participants, 178 (41.3%), 63 (14.6%), and 58 (13.2%) were nurses, doctors, and cleaners respectively (Fig 1).

Knowledge of health care workers
From the total health care workers, 290 (67.3%) HCWs knew the benefit of BMWM. About 269(62.4%), and 283(65.7%) were aware that infectious and general wastes, should be placed in

Table 1. Socio-demographic variables for BMWM among HCWs at metropolitan cities private hospitals of Amhara region, Ethiopia, December 2020.

| Variables         | Response category | Frequency (n = 431) | Percent |
|-------------------|-------------------|---------------------|---------|
| Sex               | Male              | 186                 | 43.2    |
|                   | Female            | 245                 | 56.8    |
| Age in years      | <25               | 91                  | 21.1    |
|                   | 26–30             | 203                 | 47.1    |
|                   | 31–35             | 101                 | 23.4    |
|                   | >35               | 36                  | 8.4     |
| Religion          | Orthodox          | 400                 | 92.8    |
|                   | Muslim            | 25                  | 5.8     |
|                   | Protestant        | 6                   | 1.4     |
| Marital status    | Single            | 174                 | 40.4    |
|                   | Married           | 257                 | 59.6    |
| Ethnicity         | Amhara            | 422                 | 97.9    |
|                   | Others            | 9                   | 2.1     |
| Level of education| MSc and above     | 15                  | 3.5     |
|                   | First Degree      | 256                 | 59.4    |
|                   | Diploma           | 148                 | 34.3    |
|                   | Certificate and bellow | 12 | 2.8 |
| Work experience   | <1 year           | 50                  | 11.6    |
|                   | 1–5 years         | 157                 | 36.4    |
|                   | >5 years          | 224                 | 52.0    |

https://doi.org/10.1371/journal.pone.0266037.t001
### Table 2. HCF related factors for BMWM among HCWs at metropolitan cities private hospitals of Amhara region, Ethiopia, 2020.

| Variables                              | Response category | Frequency (n = 431) | Percent |
|----------------------------------------|-------------------|---------------------|---------|
| Taken training on BMWM                | Yes               | 199                 | 46.2    |
|                                        | No                | 232                 | 53.8    |
| Working hours per day                  | 8 hours           | 388                 | 90.0    |
|                                        | >8 hours          | 43                  | 10.0    |
| Working departments                    | OPD               | 155                 | 36.0    |
|                                        | Ward              | 132                 | 30.6    |
|                                        | Laboratory        | 44                  | 10.2    |
|                                        | Emergency         | 45                  | 10.4    |
|                                        | Pharmacy          | 32                  | 7.4     |
|                                        | Others*           | 23                  | 5.3     |
| Glove availability in working department | Yes              | 172                 | 39.9    |
|                                        | No                | 151                 | 35.0    |
|                                        | Not applicable    | 108                 | 25.1    |
| Guideline availability for BMWM or IPC | Yes               | 241                 | 55.9    |
|                                        | No                | 190                 | 44.1    |
| Infectious waste stored more than two days | Yes             | 166                 | 38.5    |
|                                        | No                | 265                 | 61.5    |
| Availability of 3 bins                 | Yes               | 223                 | 51.7    |
|                                        | No                | 208                 | 48.3    |
| Leveled bins availability              | Yes               | 371                 | 86.1    |
|                                        | No                | 60                  | 13.9    |

**x-ray and OR.

https://doi.org/10.1371/journal.pone.0266037.t002

---

**Fig 1.** Profession or job distribution of health care workers in metropolitan cities private hospitals of Amhara region 2020.

https://doi.org/10.1371/journal.pone.0266037.g001
yellow, and black, respectively. Besides, 233 (54.1%) were aware of a safety box should be filled a maximum of 3/4. 168 (39%) health care workers knew the maximum storage time (48 hours) limit of infectious wastes before treatment or disposal. Based on the summary of knowledge questions the mean score of HCW’s knowledge in biomedical waste management was 7.96 with SD ±1.50 on a range of 1 to 13 questions. More than half, (62.4%) of Health care workers had good knowledge about biomedical waste management (Table 3).

### The attitude of health care workers

Among all Health care workers, 174 (40.4%) strongly agreed with the statement proper biomedical waste disposal is important and 167 (34.7%) health care workers strongly agreed with the statement BMWs should be segregated into different categories. Based on the summary of Attitude questions, the mean score of HCW’s Attitude in biomedical waste management was 53.68 with SD ±8.753 on a range of 1 to 14 questions. More than half (53.4%) of Health care workers had a good attitude about biomedical waste management (Table 4).

| Variables                                                                 | Response category | Frequency (n = 431) | Percent |
|---------------------------------------------------------------------------|-------------------|---------------------|---------|
| Know health hazards mainly associated with BMWs?                           | Yes               | 317                 | 73.5    |
|                                                                           | No                | 114                 | 26.5    |
| Does wearing PPE reduce the risk of infection?                            | Yes               | 309                 | 71.7    |
|                                                                           | No                | 122                 | 28.3    |
| Are all BMWs biologically hazardous (infectious)?                         | Yes               | 240                 | 55.7    |
|                                                                           | No                | 191                 | 44.3    |
| Are items contaminated with body fluids considered as BMW?                | Yes               | 315                 | 73.1    |
|                                                                           | No                | 116                 | 26.9    |
| Do you know as BMWs are segregated into different categories?             | Yes               | 304                 | 70.5    |
|                                                                           | No                | 127                 | 29.5    |
| Do you know about the color-coding of BMW bins?                           | Yes               | 304                 | 70.5    |
|                                                                           | No                | 127                 | 29.5    |
| What type of BMW should be stored in a yellow bin?                         | General waste     | 139                 | 32.3    |
|                                                                           | Infectious waste  | 269                 | 62.7    |
|                                                                           | I don’t know      | 23                  | 5.3     |
| What type of BMW should be stored in a black bin?                         | General waste     | 283                 | 65.7    |
|                                                                           | Infectious waste  | 93                  | 21.6    |
|                                                                           | I don’t know      | 55                  | 12.8    |
| What type of BMW should be stored in a safety box?                        | Sharp wastes      | 336                 | 78.0    |
|                                                                           | Plastic wastes    | 67                  | 15.5    |
|                                                                           | Paper wastes      | 28                  | 6.5     |
| Does disinfection of infectious BMWs decrease infection?                  | Yes               | 351                 | 81.4    |
|                                                                           | No                | 80                  | 18.6    |
| Is there a need to close BMW containers while transport?                  | Yes               | 326                 | 75.6    |
|                                                                           | No                | 105                 | 24.4    |
| Is there a need to secure stored BMWs waiting for treatment or disposal?  | Yes               | 341                 | 79.1    |
|                                                                           | No                | 90                  | 20.9    |
| Do you know about BMW disposal methods?                                   | Yes               | 308                 | 71.5    |
|                                                                           | No                | 123                 | 28.5    |
| Summary of BMWM Knowledge                                                  | Good knowledge    | 269                 | 62.4    |
|                                                                           | Poor knowledge    | 162                 | 37.6    |

Table 3. Frequency of health care workers among each knowledge term question at metropolitan cities private hospitals of Amhara region, Ethiopia, 2020.
The practice of Health care workers

This study revealed that 98 (22.7%) health care workers encountered sharp injury at their health care service delivery. Regarding PPE, 337 (78.2%) and 332 (77.0%) of HCWs always used gloves and gowns while handling or working with BMWs respectively. Based on the summary of practice questions, the mean score of HCWs practice in this study was 6.77 with SD ±1.42 on a range of 1 to 12 questions. Less than half (49.4%) of health care workers had a good practice of biomedical waste management with (95% CI: 44.6%, 54.2%) (Table 5).

Among the studied participants, HCWs who had high scores of biomedical waste management practice 66% and 60.7% were medical doctors and nurses respectively. whereas HCWs who had list scores of BMWM practice 17.5% and 5.9% were cleaners and radiographers respectively (Fig 2).

Observation result

In the selected private hospital of each metropolitan city, observation was done at seven working departments such as OPDs, wards, laboratory, emergency, maternity, minor OR, pharmacy, and X-ray rooms of health care workers. Regarding the working department, more than half (62.5%) of departments had visual aid of biomedical waste containers. Gloves were

Table 4. Frequency of health care workers among each attitude item question at metropolitan cities private hospitals of Amhara region, Ethiopia, 2020.

| Variables                                                | Disagree | Neutral | Agree     |
|----------------------------------------------------------|----------|---------|-----------|
| Improperly managed BMWs may cause infection              | 86(20.0) | 42(9.7) | 303(70.3) |
| Safe BMWM is an issue involving the responsibilities of every health care staff | 40(9.3)  | 44(10.2) | 347(80.5) |
| HIV may be transmitted through BMWs                      | 68(15.8) | 48(11.1) | 315(73.1) |
| Hepatitis B virus may be transmitted through BMWs        | 64(14.8) | 36(8.4)  | 331(76.8) |
| Hepatitis C virus may be transmitted through BMWs        | 72(16.7) | 84(19.5) | 275(63.8) |
| BMWs do not transmit any infectious diseases             | 275(63.8)| 65(15.1) | 91(21.1)  |
| BMWs should be segregated into different categories at the point of generation | 72(16.7)| 52(12.1) | 307(71.2) |
| BMW’s segregation facilitates safe handling of the waste | 60(13.9) | 36(8.4)  | 335(77.7) |
| Labeling BMWs containers does not add value to BMWM     | 251(58.2)| 44(10.2) | 136(31.6) |
| Proper biomedical waste disposal is important to prevent infection transmission | 64(14.8) | 12(2.8)  | 355(82.4) |
| BMW’s disinfection can reduce the chance of contracting an infection | 62(14.4) | 40(9.3)  | 329(76.3) |
| Wearing PPE helps to reduce the risk of infection       | 52(12.1) | 48(11.1) | 331(76.8) |
| BMW adds the extra burden of work                       | 235(54.5)| 72(16.7) | 124(28.8) |
| Biohazards wastes should be disinfected before disposal | 100(23.2)| 36(8.4)  | 295(68.4) |
| Summary of BMWM Attitude score                          |          |         |           |
| Good attitude                                           | 230      |         | 53.4      |
| Poor attitude                                           | 201      |         | 46.6      |

https://doi.org/10.1371/journal.pone.0266037.t004

The practice of Health care workers

This study revealed that 98 (22.7%) health care workers encountered sharp injury at their health care service delivery. Regarding PPE, 337 (78.2%) and 332 (77.0%) of HCWs always used gloves and gowns while handling or working with BMWs respectively. Based on the summary of practice questions, the mean score of HCWs practice in this study was 6.77 with SD ±1.42 on a range of 1 to 12 questions. Less than half (49.4%) of health care workers had a good practice of biomedical waste management with (95% CI: 44.6%, 54.2%) (Table 5).

Among the studied participants, HCWs who had high scores of biomedical waste management practice 66% and 60.7% were medical doctors and nurses respectively. whereas HCWs who had list scores of BMWM practice 17.5% and 5.9% were cleaners and radiographers respectively (Fig 2).

Observation result

In the selected private hospital of each metropolitan city, observation was done at seven working departments such as OPDs, wards, laboratory, emergency, maternity, minor OR, pharmacy, and X-ray rooms of health care workers. Regarding the working department, more than half (62.5%) of departments had visual aid of biomedical waste containers. Gloves were
available for each patient care cleaning device in all departments, except outpatient pharmacy departments. Three color-coding bins and leveled bins were available in Laboratory, Emergency, Maternity, and Minor OR departments, but not in other departments. The autoclave was available in some departments (maternity, Laboratory, and minor OR) but not in other departments rather it was available as a health care facility level in one fixed area. Personal protective equipment like heavy-duty gloves, aprons, and boots was available in maternity, emergency, laboratory, and minor OR rooms but not in others.

Regarding health care facilities, 37.5% of them had onsite storage rooms of biomedical wastes. The infection prevention and control committee was available only in two of them. All private hospitals had an incinerator, but it was not fenced (except one general hospital). Infection prevention and control guidelines were available in some hospitals’ infection prevention offices rather than in each working department. A placenta pit was available in all private hospitals.

Factors associated with biomedical waste management practice

In the bi-variable binary logistic regression analysis; age, attitude, knowledge of HCWs, level of education, training, availability of three bins, information about biomedical waste,
information about biomedical waste management, and work experience were factors associated with biomedical waste management practice.

To start with the findings of socio-demographic factor, the odds of good biomedical waste management practice was found to increase by more than 4 times among health care workers who hold MSc and above the level of education when compared with a diploma and below [AOR = 4.20, 95% CI: (1.01, 17.40)].

Health care workers who took training on biomedical waste management had an association with biomedical waste management practice. Health care workers who took training [AOR = 4.33, 95% CI: (2.71, 6.93)] were 4.3 times more likely to practice good biomedical waste management than their counterparts.

The availability of three bins (black bin, yellow bin, and safety box) in the working department was associated with good biomedical waste management practice. Availability of three bins in the working department [AOR = 6.24, 95% CI (3.84, 10.13)] was 6.2 times more likely to practice good biomedical waste management than not the availability of three bins.

Health care workers who had a good attitude [(AOR = 2.64, 95% CI: (1.65, 4.22)] were 2.6 times more likely to practice good biomedical waste management than those who had a poor attitude (Table 6).

**Discussion**

In this study, 213 (49.4%) health care workers had a good practice of BMWM with (95% CI: 44.6%, 54.2%). This finding is in line with the finding of two previous studies done in South Africa and Biyem-Assi District Hospital in Yaoundé, which reported 53.9% and 50% respectively [45,46]. However, the finding of this study is found to be higher than the findings of three studies done in Rwanda, Jigjiga, and Gondar town, which reported 33.5%, 42.3%, and 31.5 of good practices respectively. [39,47,48]. This disagreement might be partly explained by
a difference in health facility setup, since the above-mentioned studies (Jigjiga and Gondar) had a mixing of hospitals and health centers and the other study (in Rwanda) had only one district hospital. But the current study included only general hospitals. So, hospitals might have good practice of BMWM due to the presence of health care workers who had a high level of education than the health centers. But, the finding of this study is found to be lower than the finding of other previous studies done at Debre Markos Town in Ethiopia, in a tertiary hospital in Puducherry (Southern India) and Mahatma Gandhi Government Hospital of India, which reported 78.9%, 69.3%, and 54.7% were found respectively [43,49,50]. The low level of practice shown in this study might be due to the more availability of 3 bins in 81.4% of health care workers in their working department at Debre Markos Town than the current studied health care workers (51.7%) and cultural differences of Indian health care setup and this local area.

In the present study, there was a significant association between the level of education and biomedical waste management practices. Health care workers who held MSc and above education level were 4.20 times more likely to practice good biomedical waste management than those who were diploma and below and health care workers who were degree level of education also were 3.52 times more likely to practice good biomedical waste management than

Table 6. Multivariable binary logistic regression analysis for factors associated with biomedical waste management practices among health care workers in metropolitan cities private hospitals of Amhara region, Ethiopia 2020.

| Variables                        | BMWM practices | COR (95% CI)       | AOR (95% CI)       |
|----------------------------------|----------------|--------------------|--------------------|
|                                  | Good           | Poor               |                    |
| Age < 25 years                   | 35             | 56                 | 1.78(1.08,2.95)    | 1.42(0.70,2.91) |
| 26–30 years                     | 107            | 96                 | 1.51(0.85,2.68)    | 0.77(0.34,1.74) |
| 31–35 years                     | 49             | 52                 | 2.51(1.14,5.35)    | 1.40(0.46,4.26) |
| >35 years                       | 22             | 14                 |                    |                   |
| Level of education              |                |                    |                    |                   |
| MSc and above                   | 9              | 4                  | 4.18(1.23,14.19)   | 4.20(1.01,17.40)  |
| First degree                    | 147            | 108                | 2.53(1.68,3.80)    | 3.52(2.13,5.82)   |
| Diploma and below               | 57             | 106                | 1                  | 1                  |
| Taking training                 |                |                    |                    |                   |
| Yes                              | 139            | 60                 | 4.95(3.28,7.45)    | 4.33(2.71,6.93)   |
| No                              | 74             | 158                | 1                  | 1                  |
| Availability of three bins      |                |                    |                    |                   |
| Yes                              | 154            | 69                 | 5.64(3.73,8.53)    | 6.24(3.84,10.13)  |
| No                              | 59             | 149                | 1                  | 1                  |
| Got information on BMWs         |                |                    |                    |                   |
| Yes                              | 174            | 163                | 1.51(0.95,2.39)    | 0.75(0.37,1.54)   |
| No                              | 39             | 55                 | 1                  | 1                  |
| Got information on BMWM          |                |                    |                    |                   |
| Yes                              | 176            | 156                | 1.89(1.19,2.99)    | 1.61(0.91,2.86)   |
| No                              | 37             | 62                 | 1                  | 1                  |
| Attitude of HCWs                |                |                    |                    |                   |
| Good                             | 140            | 90                 | 2.73(1.85,4.03)    | 2.64(1.65,4.22)   |
| Poor                             | 73             | 128                | 1                  | 1                  |
| Knowledge of HCWs               |                |                    |                    |                   |
| Good                             | 139            | 130                | 1.27(0.86,1.88)    | 1.46(0.89,2.38)   |
| Poor                             | 74             | 88                 | 1                  | 1                  |
| Work experience                  |                |                    |                    |                   |
| < 1 year                         | 20             | 30                 | 1                  | 1                  |
| 1–5 years                        | 70             | 87                 | 1.21(0.63,2.31)    | 0.85(0.39,1.88)   |
| >5 years                         | 123            | 101                | 1.83(0.98,3.41)    | 1.46(0.68,3.14)   |

* = p-value < 0.05
***p-value < 0.001, Hosmer and Lemshow goodness of fit test = 0.839.

https://doi.org/10.1371/journal.pone.0266037.t006
those who were diploma and below. This finding was similar to the finding of a study done in the Capital city of Uganda [51]. This indicates that educational status development helps to improve the practice of health care workers on biomedical waste management [52].

The other finding worth highlighting is related to training, a significant association between taking training and biomedical waste management practice was found. Health care workers who took training on BMWM had 4.33 times more likely to practice good biomedical waste management than those who didn’t take the training. This finding was in agreement with the previous studies conducted in Gondar town, Ethiopia, and the capital city of Uganda [48,51]. It is due to getting waste management training of all those who are responsible for handling wastes is important to improve BMWM [53,54].

Availability of color-coded three bins was significantly associated with biomedical waste management practice. Health care workers who had three bins in their working department were 6.24 times more likely to practice biomedical waste management than those who had no three bins. The finding was supported by the previous study done in Debre Markos town, Ethiopia [43]. This is due to the availability of three bins that make waste segregation being simple and safe to separate hazardous wastes from non-hazardous general wastes [55].

The attitude of health care workers was significantly associated with biomedical waste management practice. Health care workers who had a good attitude toward BMWM had 2.64 times more likely to practice good biomedical waste management than those who had a poor attitude toward BMWM. This finding was supported by the studies done in Biyem-Assi District Hospital in Yaoundé (Cameroon) and Agartala, Tripura (North-eastern India) [45,56]. The possible explanation might be due to a good attitude of health care workers helps to practice good biomedical waste management; because the level of attitude was one of the factors, which affect practice as seen in other studies. The study was conducted in all metropolitan cities’ private hospitals of the Amhara region, which covered all private hospitals in three cities. But there may be socially desirable bias for the practice of BMWM during data collection time. In this study, the quantification of the generation rate of biomedical wastes should have been measured.

**Conclusion**

Biomedical waste management practice was low among health care workers which is a risk of COVID 19 pandemic transmission. The level of education, taking training on BMWM, availability of three bins, and attitude of health care workers was found to have a significant association with biomedical waste management practice. Therefore, it was determined that it is better to provide in-service training programs on biomedical waste management and upgrade their educational level for health care professionals by regional health bureau and city administration health departments, as well as it is recommended to implement a three-bin system in the hospitals. Finally, all private hospitals should acknowledge the health care workers who practiced good biomedical waste management.

Although the study was conducted in private hospitals, the health tier system in Ethiopia both for private and public Hospitals is similar except for the ownership. Therefore, the finding can apply to other similar public hospitals within and across regions as well as in the least and middle-income countries.

**Supporting information**

S1 File. Data collection tool English version. (PDF)
Acknowledgments
We acknowledge data collectors and supervisors for their contribution to the overall success of this study and all respondents for their cooperation, time, and genuine response. Our great thanks go to Dr. Mesafint Molla and Francesco Giulietti for their support in editing the language of the manuscript.

Author Contributions
Conceptualization: Getasew Mitiku, Amha Admasie, Amsalu Birara.
Formal analysis: Getasew Mitiku, Amha Admasie, Amsalu Birara, Wubante Yalew.
Investigation: Getasew Mitiku.
Methodology: Amha Admasie, Amsalu Birara.
Software: Getasew Mitiku, Amha Admasie, Amsalu Birara, Wubante Yalew.
Supervision: Amsalu Birara.
Validation: Amha Admasie.
Writing – original draft: Getasew Mitiku, Amha Admasie, Amsalu Birara.
Writing – review & editing: Amha Admasie, Wubante Yalew.

References
1. Karmakar N, Datta SS, Datta A, Nag K (2016) A cross-sectional study on knowledge, attitude and practice of biomedical waste management by health care personnel in a tertiary care hospital of Agartala, Tripura. Natl J Res Commun ity Med 5: 189–195.
2. Singhal L, Tuli AK, Gautam V (2017) Biomedical waste management guidelines 2016: What’s done and what needs to be done. Indian J Med Microbiol 35: 194–198. https://doi.org/10.4103/ijmm.IJMM_17_105 PMID: 28681805
3. Oli AN, Ekejind u CC, Adje DU, Ezeobi I, Ejiofor OS, et al. (2016) Healthcare waste management in selected government and private hospitals in Southeast Nigeria. Asian Pacific Journal of Tropical Bio-medicine 6: 84–89.
4. Singh H, Rehman R, Bumb SS (2014) Management of biomedical waste: a review. International Journal of Dental and Medical Research 1: 14–20.
5. Chuks N, Anayo F, Ugbogu OC (2013) Health Care Waste Management–Public Health Benefits, and the Need for Effective Environmental Regulatory Surveillance in Federal Republic of Nigeria. https://doi.org/10.1016/j.jenvman.2013.05.027 PMID: 23764471
6. Arab M, Baghbane RA, Tajvar M, Pourreza A, Tajvar M, et al. (2008) Report: The assessment of hospital waste management: a case study in Tehran. Waste management & research 26: 304–308. https://doi.org/10.1177/0734242X08093598 PMID: 18649580
7. Sarker MAB, Harun-Or-Rashid M, Hirosawa T, Hai MSBA, Siddique MRF, et al. (2014) Evaluation of knowledge, practices, and possible barriers among healthcare providers regarding medical waste management in Dhaka, Bangladesh. Medical science monitor: international medical journal of experimental and clinical research 20: 2590.
8. Sharma M, Uppadhyaya SK (2019) ASSESSMENT OF KNOWLEDGE AND PRACTICE ABOUT BIO-MEDICAL WASTE MANAGEMENT AND ASSOCIATED FACTORS AMONG HEALTH CARE PER-SONNEL IN A PUBLIC HOSPITAL OF RAJASTHAN. International Journal of Scientific Research 8. https://doi.org/10.15373/22778179 PMID: 31089180
9. COLLEGE GM, & HOSPITAL-32 C (2014) MANUAL FOR BIOMEDICAL WASTE MANAGEMENT. Nigerian Journal of Medical Sciences. https://doi.org/10.4317/jced.51565 PMID: 25593667

10. Harhay MO, Halpern SD, Harhay JS, Olliaro PL (2009) Health care waste management: a neglected and growing public health problem worldwide. Tropical Medicine & International Health 14: 1414–1417. https://doi.org/10.1111/j.1365-3156.2009.02386.x PMID: 19735368

11. Al-Khatib IA, Sato C (2009) Solid health care waste management status at health care centers in the West Bank–Palestinian Territory. Waste management 29: 2398–2403. https://doi.org/10.1016/j.wasman.2009.03.014 PMID: 19398317

12. Sehgal RK, Garg R, Dhot PS, Singhal P (2015) A study of knowledge, attitude, and practices regarding biomedical waste management among the health-care workers in a multispecialty teaching hospital at Delhi. International Journal of medical science and Public Health 4: 1536–1541.

13. Organization WH (2002) Basic steps in the preparation of health waste management plans for health care establishments.

14. Datta P, Mohi GK, Chander J (2018) Biomedical waste management in India: Critical appraisal. J Lab Physicians 10: 6–14. https://doi.org/10.4103/JLP.JLP_89_17 PMID: 29403196

15. Parida A, Capoor MR, Bhowmik KT (2019) Knowledge, attitude, and practices of bio-medical waste management rules, 2016; bio-medical waste management (amendment) rules, 2018; and solid waste rules, 2016, among health-care workers in a tertiary care setup. Journal of laboratory physicians 11: 292–296. https://doi.org/10.4103/JLP.JLP_88_19 PMID: 31929693

16. Asadullah K, Karthik G, Dharmappa B (2013) A study on knowledge, attitude and practices regarding biomedical waste management among nursing staff in private hospitals in udupi city, karnataka, India. Revista Internacional de Geología, Ciencias Terrestres y Ambientales 3: 118–123.

17. Esubalew T (2007) Assessment of health care waste generation rate and evaluation of health care waste management in Debre Birhan zonal hospital. Ethiopia.

18. Authority FEP (2004) Technical guidelines on the environmentally sound management of biomedical and healthcare wastes. Addis Ababa Ethiopia.

19. Food MaHAaCAF (2005) Healthcare waste management directive. Addis Ababa: Food, Medicine and Healthcare Administration and Control Authority (FMHACA).

20. Demissie F (2014) Hazardous waste management by healthcare institutions, Addis Ababa: implementation of laws and regulation. Ethiopian Journal of Environmental Studies and Management 7: 134–141.

21. Haylamichael ID, Desalegne SA (2012) A review of legal framework applicable for the management of healthcare waste and current management practices in Ethiopia. Waste management & research 30: 607–618. https://doi.org/10.1177/0734242X11419891 PMID: 21987414

22. Yu H, Sun X, Solvang WD, Zhao X (2020) Reverse logistics network design for effective management of medical waste in epidemic outbreaks: Insights from the coronavirus disease 2019 (COVID-19) outbreak in Wuhan (China). International journal of environmental research and public health 17: 1770.

23. Agrawal A, Dodamani A, Vishwakarma P, Agrawal A (2020) Biomedical Waste and COVID-19 in India and the World: Are We Ready? International Journal of Medical Reviews 7: 124–130.

24. Das AK, Islam MN, Billah MM, Sarker A (2021) COVID-19 and municipal solid waste (MSW) management: a review. Environ Sci Pollut Res Int 28: 28993–29008. https://doi.org/10.1007/s11356-021-13914-6 PMID: 33877522

25. Ministry of Environment FaCC, Govt. of India (2019) Annual report 2018–19, Plastic Waste Management Rules (As per Rule ‘17(4)’ of PWM Rules, 2016)

26. Mekonnen B, Solomon N, Wondimu W (2021) Healthcare Waste Status and Handling Practices during COVID-19 Pandemic in Tepi General Hospital, Ethiopia. Journal of Environmental and Public Health 2021. https://doi.org/10.1155/2021/6614565 PMID: 33564314

27. WHO (2018) Fact sheet on Health care waste management. Available from: https://www.who.int/news-room/fact-sheets/detail/health-care-waste.

28. Attafu DD, Kurnie A (2017) Healthcare waste composition and generation rate in Menelik II Referral Hospital, Addis Ababa, Ethiopia: a cross sectional study. International Journal of Sustainability Management and Information Technologies 3: 10–19.

29. Meleko A, Adane A (2018) Assessment of health care waste generation rate and evaluation of its management system in Mизan Tepi University Teaching Hospital (MUTH), Bench Maji Zone, South West Ethiopia. Ann Rev Res 1: 1–9.

30. Lemma H, Dadi D, Deti M, Fekadu S (2021) Biomedical Solid Waste Management System in Jimma Medical Center, Jimma Town, South Western Ethiopia. Risk Management and Healthcare Policy 14: 4037. https://doi.org/10.2147/RMHP.S315446 PMID: 34611452
31. Kanno GG, Gondol BN, Mamo TT, Areba AS, Lagiso ZA, et al. (2021) Healthcare Waste Generation, Composition and management Practice in Dilla University Referral Hospital: A cross-sectional study.
32. TESFAHUN E (2015) HEALTHCARE WASTE IN ETHIOPIA A STUDY OF WASTE GENERATION, COMPOSITION AND MANAGEMENT IN THE AMHARA NATIONAL REGIONAL STATE, ETHIOPIA.
33. Kasahun AsFA (2014) A Public–Private Partnership Framework for a Common Health Care Waste Treatment Facility for Addis Ababa City. Arlington, VA: AIDSTAR-One. https://doi.org/10.1016/j.ympev.2014.07.023 PMID: 25109650
34. Berihun D, Solomon Y (2017) Preliminary Assessment of the Status of Hospital Incineration Facilities as a Health Care Waste Management Practice in Addis Ababa City, Ethiopia. Adv Recycling Waste Manag 2: 2.
35. Sawalem M, Selic E, Herbell J-D (2009) Hospital waste management in Libya: A case study. Waste management 29: 1370–1375. https://doi.org/10.1016/j.wasman.2008.08.028 PMID: 19036572
36. Akter N (2000) Medical Waste management: A review: Asian institute of Technology: Thailand Armstrong BA and Reinhardt PA, 2010. Managing laboratory biomedical waste using a large on-site autoclave–shredder. Journal of Chemical Health and Safety 17: 33–39.
37. Ethiopia FDRo, Health Mo (2019) Infection Control and Waste Management Plan (ICWMP) For Bio-safety Level Three (BSL3) National Reference.
38. Hanumantha Rao P (2008) Report: Hospital waste management—awareness and practices: a study of three states in India. Waste management & research 26: 297–303. https://doi.org/10.1177/0734242X08088693 PMID: 18649579
39. 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 Community Health 44: 284–291. https://doi.org/10.1007/s10900-018-0584-z PMID: 30341746
40. Haile TG, Engeda EH, Abdo AA (2017) Compliance with standard precautions and associated factors among healthcare workers in Gondar University Comprehensive Specialized Hospital, Northwest Ethiopia. Journal of environmental and public health 2017. https://doi.org/10.1155/2017/2050635 PMID: 28191020
41. Doylo T, Alemayehu T, Baraki N (2019) Knowledge and practice of health workers about healthcare waste management in public health facilities in Eastern Ethiopia. Journal of community health 44: 284–291. https://doi.org/10.1007/s10900-018-0584-z PMID: 30341746
42. Hayleyeyses SF, Cherinet W (2016) Healthcare waste generation and management in public health-care facilities in Adama, Ethiopia. Journal of Health and Pollution 6: 64–73. https://doi.org/10.5696/2156-9614-6-10.64 PMID: 30524786
43. Deress T, Hassen F, Adane K, Tsegaye A (2018) Assessment of Knowledge, Attitude, and Practice about Biomedical Waste Management and Associated Factors among the Healthcare Professionals at Debre Markos Town Healthcare Facilities, Northwest Ethiopia. J Environ Public Health 2018: 7672981. https://doi.org/10.1155/2018/7672981 PMID: 30386382
44. Abebe S, Raju R, Berhanu G (2017) Health care solid waste generation and its management in Hawassa Referral Hospital of Hawassa University, Southern, Ethiopia. Int J Innov Res Dev 6: 126–132.
45. Woromogo SH, Djeukang GG, Yagata Moussa FE, Saba Antaon JS, Kort KN, et al. (2020) Assessing Knowledge, Attitudes, and Practices of Healthcare Workers regarding Biomedical Waste Management at Biyem-Assi District Hospital, Yaounde: A Cross-Sectional Analytical Study. Advances in Public Health 2020: 1–7.
46. Olaifa A, Govender RD, Ross AJ (2018) Knowledge, attitudes and practices of healthcare workers about health care waste management at a district hospital in KwaZulu-Natal. South African Family Practice 60: 137–145.
47. Rutayisire E, Nsabimana JA, Habtu M, Mango L (2019) Knowledge and Practice for Bio-Medical Waste Management among Healthcare Personnel at Kabgayi District Hospital, Rwanda. Journal of Public Health International 1: 36–44.
48. Azage Muluken 1 GH, Molla 3 M (2013) Healthcare waste management practices among healthcare workers in healthcare facilities of Gondar town, Northwest Ethiopia. HEALTH SCIENCE JOURNAL 7.
49. Monika Sekar SM1, Joshy MEasow3 (2018) A study on knowledge, attitude and practice of biomedical waste management among health care workers in a Tertiary Care Hospital in Puducherry. Indian Journal of Microbiology Research 5: 57–60.
50. Kumar S, Uppadhyaya (2019) ASSESSMENT OF KNOWLEDGE AND PRACTICE ABOUT BIOMEDICAL WASTE MANAGEMENT AND ASSOCIATED FACTORS AMONG HEALTH CARE PERSONNEL IN A PUBLIC HOSPITAL OF RAJASTHAN. International Journal of Scientific Research 8. https://doi.org/10.15373/22778179 PMID: 31069180
51. Wafula ST, Musiime J, Oporia F (2019) Health care waste management among health workers and associated factors in primary health care facilities in Kampala City, Uganda: a cross-sectional study. BMC Public Health 19: 203. https://doi.org/10.1186/s12889-019-6528-4 PMID: 30777034

52. Ali (2000) Manual of waste management at medical centres.

53. Cross ICotR (2011) Medical waste management. International Journal of Advanced Community Medicine.

54. Ethiopian Food MaHAa, Authority C (2005, Addis Abeba) Healthcare Waste Management Directive.

55. WHO (2017) Safe management of wastes from health-care activities.

56. Karmakar N (2016) A cross-sectional study on knowledge, attitude and practice of biomedical waste management by health care personnel in a tertiary care hospital of Agartala, Tripura. National Journal of Research in Community Medicine 5.