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Identifying Sustainable Biomedical Solid Waste Management Practices in the Context of Limited Resources in Selected Healthcare Facilities in Douala Cameroon

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To Identify sustainable Biomedical solid waste management practices in the context of limited resources in selected HCFs in Douala, Cameroon.
Study Design: A cross-sectional survey with quantitative and qualitative study design was adopted for data collection from workers in the HCFs and also identifying the process of waste management.
Place and Duration of Study: This study was carried out in the some selected HCFs in the Douala region of Cameroon between January 2023 to June 2023.

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Methodology: Study respondents were working in different sections of the HCFs and comprised of the following categories: doctors, laboratory scientists, cleaners, nurses and administrative/clerical workers. Field visitations and interactions with HCFs officials took place during the random sampling technique which was used in determining the sample size of 200 workers, Out of the sample size of 200 who were given questionnaires in order to provide data for the study, 150 valid mail questionnaires were retrieved and used for analysis. Every questionnaire was verified by validity. There's also questions related funds, facilities availability, training and personal protective equipment. All of the data were coded and analyzed. The results were calculated based on sums and percentages of variables with SPSS vers.26 software and chi-square analysis with the level significance of p-value less than 0.05 was analyze

Results: This finding could also indicate that imbibing sustainable biomedical wastes management practices increases with higher experience in the hospital. Furthermore, communal bin disposal of biomedical wastes was the only statistically significant category under disposal method, indicating that waste disposal may be lacking in terms of sustainable practices. [30] also identified biomedical wastes disposal in open dumps among health workers in Saudi Arabia, attributable to poor sustainable waste training and lack of regulatory frameworks. I PCA results indicate that there are two dimensions of prevalent biomedical wastes in the hospital studied, as explicated by the two components retained

Conclusion: The limited resources and government policies and local councils influences sustainable waste management practices and this paper aimed at identifying some of the solutions towards improving Sustainable waste management policies. 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.

Keywords: Sustainability; waste management; limited resources; healthcare facilities; Douala.

1. INTRODUCTION

"Healthcare waste streams are persistent waste streams and which are consistently increasing in volume and complexity in developed and developing countries. When poorly managed, through inappropriate healthcare waste management system, they can cause adverse effects to human health and the environment. As many cities and towns around the world continue to grow due to factors such as urbanization, industrialization, and globalization, biomedical waste management (BWM) has consequently become a serious concern to governments worldwide" [1]. In hospitals, various categories of waste are produced as workers try to improve health conditions of patients and visitors to the health facility. Due to its hazardous nature, management and disposal of BSW should carryout out sustainably, so as to reduce environmental health and safety impacts [2]. Sustainable management of BW means that concepts like reduce, reuse, recycling, incineration and lifecycle assessment are applied in the collection, segregation, storage, transportation, treatment and disposal of waste materials generated from hospitals [1,2]. Due to the nature of activities that take place in hospitals, sharps (needles, syringes etc.), used bandages/pads/gloves/plasters/gauze, body tissues, drugs, chemicals, fecal/urinary/blood remains, tubing, plastic/glass bottles and disposable materials/cartons as the predominant waste types generated. Furthermore, HCW generated in hospitals can be categorized as infectious, pathological, radioactive, sharps, pharmaceutical, genotoxic, laboratory, vaccine and general wastes.

"In the twenty-first century, waste management has been a widely discussed topic around the world, due to its potential for contributing to environmental and socio-economic development. However, governments in low-income countries spend only 20% of local budgets on waste management leading to lacks of skills, poor infrastructure and institutional setup, and deficits in financial and technical resources which resulted in insufficient and inefficient provision for waste management at many levels, (93% of waste in these countries is either dumped or burned in the open air landfills contributing to climate change)"[3,4]. "The impact of poor waste management has fallen disproportionately on the

poverty-stricken communities that have little or no influence on the waste products being illegally dumped near their communities" [5]. "A waste management system consists of appropriate segregation and disposal, with the inclusion of transportation, storage and training facilities for workers. An effective BSW management system is often administered by local authorities, with confined capacity for planning, restricted resources, operational monitoring and contract management. These limiting factors make sustainable waste management a difficult proposition" [6]. "The aspect of sustainability and sustainable waste management in this review is the reduction of biomedical waste that is released into the environment by reducing the volume of waste produced" [7,8].

"Cameroon is still plagued and burdened by poverty, resulting in improper burning of all classes of waste with little to no resolution of this issue in sight. The recent influx of the population into the Douala City due to the two Anglophone crises has led to increase the number of HealthCare Facilities and hence increase in the BSW production. Health systems are essential in order to attain and preserve social health and well-being are key factors to growth. It is becoming clear that appropriate organizational changes, health policy reformation, operational procedures, and management models should be made in order to achieve the sustainability of health systems and the health sector in general (sustainable healthcare)" [9]. The WHO [10] defines Environmentally Sustainable Health as a system that "improves, maintains or restores health, while minimizing negative impacts on the environment and leveraging opportunities to restore and improve it, to the benefit of the health and well-being of current and future generations".

According to Namany et al. [11], "limited resources and unsustainable consumption could possibly result in ecological collapse and resource exhaustion, so it is imperative to have total resource efficiency in order to be sustainable so as to consume less resources and produce less waste but, at the same time, offer the same quality of services in the healthcare sector" [12]. "Therefore, healthcare providers, hospitals and healthcare systems, in general, need to alter their overall strategy in terms of sustainable development and through environmental sustainable transformation, so as to perform all the necessary actions, such as addressing and management of environmental risks, the adoption of the proper environmental and sustainable management policies and training, and the implementation of other initiatives in an efficient way in order to improve their reputation, reduce their operational costs and improve profitability because of the better energy efficiency, increase their staff's satisfaction and retention, manage potential risks and comply with the legal framework in which they operate, and present a more eco-friendly and socially responsible image to its interested parties" [13,14]. "Moreover, it is essential to minimize and adequately manage BWs and hazardous chemicals through the implementation of proper waste management methodologies, promote an efficient management of resources and sustainable procurements, introduce and monitor specific KPIs, reduce the health systems' emissions of greenhouse gases and air pollution, engage the health workforce, and implement the respective tools in order to minimize the threats of the environment and to protect it" [15]. "Almost three years after the beginning of the pandemic of COVID-19 and its high rates of contagiousness, it is becoming more important for each healthcare system to have an effective and sustainable medical waste management system in order to protect public health" [16].

"Generally, various waste streams are reusable and compostable, which can generate income if managed appropriately in the global market" [16]. "Hence, many people recognise waste as a potential secondary resource that should be handled with care to ensure both short- and long-term resource availability" [17]. "Informal waste sectors, which are most prevalent in African countries, view waste as a substantial source of income that has already improved many livelihoods" [18,19]. "Again, making new products is often an expensive and energy-intensive process, which is why participants in the informal waste sector opt for waste recycling and reusing" [16]. Recycling and reusing of waste materials are activities that are already making a significant and widespread contribution to sustainable production and resource efficiency.

"Throughout Douala, the government and private hospitals have not shown a significant difference in the way medical waste is managed, with studies suggesting some healthcare workers and waste officials were not aware of policies surrounding the handling of waste nor of its final disposal method" [20,21]. "Regardless of how the institutions are funded, not all hospitals and other healthcare centres have colour-coded bags for

classified waste such as pharmaceutical, radioactive and clinical, thus rendering waste segregation impractical" [22]. "Pharmacies in Douala are not acquainted with how or where the medical waste is disposed of, and limited funding does not allow for contractual services, for example removal of medical waste, transportation and storage. This is left for the workers of the facilities in each organisation to address. Medical waste will not only debilitate the communities by hazardous waste accumulation on the land, in aquatic and aerial environments, including the presence of APIs, but will also affect the health and well-being of the entire population and national economy. If healthcare waste is segregated adequately, general waste can be harvested for bio fuels, leading the national economy in a positive direction and giving plentiful opportunities for sustainability. A proposed solution to create a reduce–reuse–recycle system can reduce medical waste and drastically change the outlook of medical waste handling while at the same adding a revenue stream" [23].

"From this background, the main objective of this study is to identify sustainable BSWM practice in the context of limited resources in selected HCFs in Douala. This objective can be achieved by studying the current situation of healthcare system in the different HCFs, identifying their challenges, finding the approaches and suggestions to overcome these challenges, strategies and action plans should be undertaken and finally presenting the policies, possible advices and solutions associated with sustainability and medical waste management that can support decision-makers in developing strategies for the sustainability by using the eco-friendly technologies for efficient medical waste treatment and disposal methods and can serve as a link between the healthcare system, decision-makers and stakeholders in developing health policies and programmes.by strengthening private/public cooperators in handling BSWM activities"[9].

1.1 Waste Management Practices in Other Countries

A review of waste management trends and practices in other similar developing countries indicates that many of them are looking towards innovative solutions to the problems of inadequate and inefficient services provided by government authorities. Numerous examples of the involvement of the private sector in service delivery, the informal sector in waste recovery and private individuals in recycling and composting initiatives, points to the realization that an effective service can be provided at reasonable cost whilst at the same time providing job creation opportunities and alleviating poverty. These logically address the reduction of waste generation by prevention and minimization, through efficient production methods and use of resources. The waste stream is also reduced through resource recovery. Finally, hazardous wastes are treated prior to final disposal to reduce the associated risks. All these elements are included in the internationally recognized Waste Management Hierarchy. Integrated Waste Management can be considered to be a different concept to the Hierarchy of Waste Management as it evaluates the mix of technologies that area appropriate to the waste stream that is being examined. In fact Life Cycle Assessment approaches are more and more being considered as they tend to lead to the development of more sustainable waste management policies, appropriate and achievable goals. Key principles, actions and suggested tools for public-private type partnerships in waste management are available from similar countries that can be readily adapted to the Douala situation.

List 1. Waste hierarchy

Cleaner production	Prevention
	Minimization
Recycling	Re-use
	Recovery
	Composting
Treatment	Physical
	Chemical
Disposal	Destruction
	Landfill

2. MATERIALS AND METHODS

2.1 Study Area

Douala is the largest city in Cameroon and its economic capital. It is also the Capital of Cameroon littoral region. With 5 768 400 inhabitants in 2015, Douala is the most populated city in Cameroon with about 4 063 000 inhabitants [18]. It is situated on the Southeastern shore of the Wouri River estuary, on the Atlantic Ocean coast about 130 miles(210km) west of Yaounde. The study area comprises of selected missionary, Public and Private HCFs within the Douala premises which includes Bonassama district hospital (BDH), Gyneco-obtetric hospital Douala (GHD), Laquintinie hospital (LH), General hospital Douala (GHD) and Acha Hospital Douala (AHD), Deido District Hospital, Help Medical Foundation, Padre Pio Sisters Hospital in the Littoral Region Cameroon as seen in Fig. 1.

2.2 Sample Size

In this study, the targeted population was those in the Healthcare facilities and waste. 200 participants were investigated in this research. The target population comprised of the following categories: doctors, laboratory scientists, cleaners, nurses, administrative/clerical workers, waste handlers and departmental heads.

2.3 Study Design and Sampling

A cross-sectional survey was adopted for data collection from workers in the selected HCFs where the study was conducted. On that note, study respondents were working in different sections of the HCFs and comprised of the following categories: doctors, laboratory scientists, cleaners, nurses and administrative/clerical workers, waste handlers and departmental heads. Field visitations and interactions with HCFs officials took place during the random sampling technique which was used in determining the sample size of 200 workers, based on sample of proportion representing about 5% of the study population. Out of the sample size of 200 who were given questionnaires in order to provide data for the study, 150 valid mail questionnaires were retrieved and used for analysis. A mixed method approach that incorporated qualitative and quantitative data collection approaches was used in this study. Structured in-depth interviews, document analysis (such as of policy documents and environmental management plans), and direct observation were methods employed to collect data. Participants were senior-level employees at selected HCFs as well as private waste management companies.

The study used a survey which aims at collecting data in order to describe the sustainable BSWM practices of the study area [24]. The study targeted 200 Health care practitioners in the selected HCFs in Douala Cameroon.

Every questionnaire was verified by validity. There's also questions related funds, facilities availability, training and personal protective equipment. All of the data were coded and analysed. The results were calculated based on sums and percentages of variables with SPSS vers.26 software and chi-square analysis with the level significance of p-value less than 0.05 was analyze.

The participants were purposely selected on the basis of being knowledgeable about the waste management systems in their respective municipalities.

Structured in-depth interviews contained predetermined questions covering the collection of both qualitative and quantitative data. The interviews lasted 25–30 min. The interview questions were mostly open, leaving space for the researcher to probe further by asking follow-up questions. It facilitated two-way communication by allowing participants to respond with open-ended questions or statements for more in-depth information and understanding [25]. Research questions were built around current municipal waste management policies, processes, procedures, and practices, and sustainable waste management and CE application in the two municipalities.

Document analysis was used to conduct a reflective/comparative scrutiny of documents (such as policies, procedures, processes, organisational strategies, and reports) as ways of providing additional data and for triangulation and confirmation of validity of the data collected through interviews. Documents provided background information and broad coverage of both qualitative and quantitative data and were therefore helpful in contextualising the research [26]. Participants were requested to provide policy documents, environmental management plans (EMPs), and other available documents for analysis.

Direct observation (landfill site visits) was conducted to observe, evaluate, and establish the current practices and operations of waste management such as waste disposal methods and recycling activities.

In order to predict the likelihood of workers being trained on sustainable management of healthcare waste (HCW), three categorical predictors were applied as independent variables in model: Occupation (Doctor, Lab scientist, Cleaner, nurse and admin/clerical), years of experience (less than 1 year, 1-5 years, 6-10 years, 11-15 years and more the 15 years) and common waste disposal method (incineration, burying, communal bin). Ethical issues were addressed in the course of the data collection process, including informed consent, confidentiality, and anonymity. Ethical approval for the research was given by the University of Douala. The purpose of the study was explained to participants and they were made aware that participation was optional. In both municipalities, participants were labelle.

2.4 Measures

In order to predict the likelihood of workers being trained on sustainable management of BSW, three important categorical predictors were applied as independent variables in model: Occupation (Doctor, Lab scientist, Cleaner, nurse and admin/clerical), years of experience (less than 1 year, 1-5 years, 6-10 years, 11-15 years and more the 15 years) and common waste disposal method (incineration, burying, communal bin). The essence of applying these variables was due to their relevance in sustainable HCW management which has been identified in literature [27]. In measuring the dimensions of prevalent BSWs, eight constructs of waste categories (pharmaceutical waste, sharps [needles/syringes/knives] waste, pathological waste, general waste, radioactive waste, genotoxic waste, laboratory waste and vaccine waste) were applied.

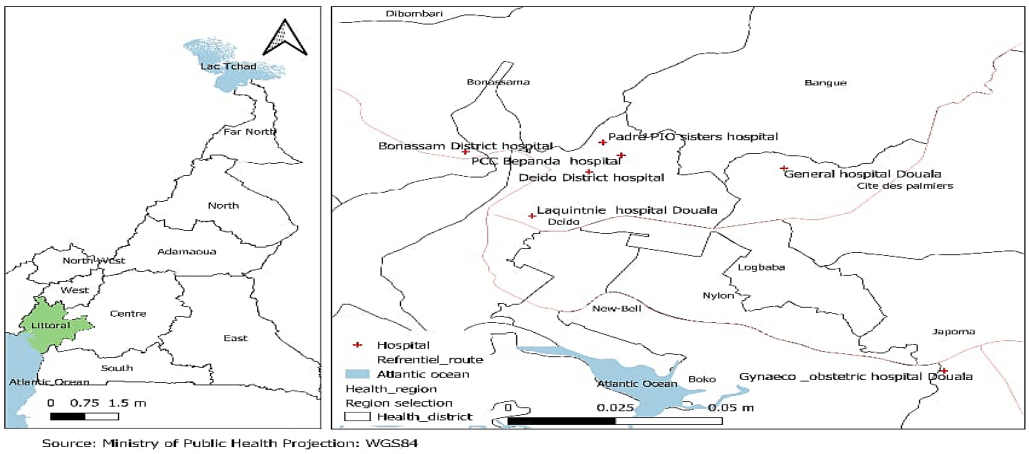
2.5 Data Analysis

IBM SPSS version 21.0 software application was applied in coding datasets and also running statistical analysis for the study. . All of the data were coded and analysed. The results were calculated based on sums and percentages of variables with SPSS vers.26 software and chi-square analysis with the level significance of p-value less than 0.05 was analyze.

In the present study, the question predicted was: Have you been trained on sustainable management of HCW? Response: Yes (1) or No (0).

Socio-demographic information of the study respondents are shown in Table 1.

In terms of gender, about 52% of the study respondents were males. Cleaners were the highest respondents at 3%. This was followed by lab scientists and nurses at 27% and 37%, respectively. Doctors comprised 20% of the study respondents while administrative/clerical workers comprised the least percentage of respondents at 3%. In terms of years of experience,5 -10 years had the most percentage of respondents at 16.0%. Workers with 11-15 years ‘experience comprised about 13% of the study respondents while 1-5 years category covered 11%.



Source: Ministry of Public Health Projection: WGS84

Fig. 1. Maps showing the study sites of the HCFs

Table 1. Socio-demographic data of hospital workers in the study (n = 234)

Variable	Categories	n
Age group	20-29	58
	30-39	67
	40-59	50
	Total	**200**
Gender	Female	96
	Male	104
	Total	**200**
Educational Level	BSc	80
	HND	54
	MSc	46
	OND	8
	PhD	12
	Total	**200**
Marital status	Divorced	6
	Married	104
	Single	90
	Total	**200**
Number of years the health facility has been in operation	Above 20 years	76
	Between 10-15 years	26
	Between 15-20years	44
	between 5-10 years	32
	Less than 5 years	22
	Total	**200**
Department you belong to	Cleaners/waste handlers	6
	Departmental head	18
	Human resource department	12
	Laboratory department	54
	Line manager	6
	Nursing department	74
	Pharmacy	8
	Surgical department	22
	Total	**200**

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Knowledge, attitude and practices (KAP) of health personnel concerning BSWMP

With regards to the knowledge of healthcare personnel on Biomedical Solid Waste Mnanagement Practices(BSWMP), 72 (72%) of the respondents had a good knowledge on BSWMP while 28 (28%) had a poor knowledge.

Fig. 2 presents the variation in the knowledge score of health personnel on BSWMP in the health facilities included in to the study. There was a lot of variation in the knowledge scores for health personnel that were working at Laquintinie, with the highest and lowest score coming from this facility while Deido District Hospital had the least variation in the knowledge score on BSWMP among its health personnel. More of the participants in laquintinie, PHC Acha St Padre and others (Nzengha Ekwekoum Annie and General hospital Douala) had knowledge score above the median score while more of the respondents in Gynaeco obstetric had knowledge scores below the median score.

3.1.2 The attitude of the health personnel towards BSWMP

The attitude of the health personnel towards BSWMP was scored on a total of 61. The mean score was 42.87±3.252. The maximum score was 52, minimum score of 31 (range=21) and a median score of 43. All the participants had a positive attitude towards BSWMP.

Fig. 3 shows the variation of the attitude scores among the health personnel in the health facilities included in to the study. The maximum score came from Bonassama district hospital while the minimum score came from Laquintinie.

Laquinitinie had the highest variation in the attitude scores among its health personnel included in to the study while Deido District hospital had the least variation in the attitude score towards BSWMP among its health personnel.

With regards to the attitude of health personnel towards BSWMP, 75(75%) of the respondents said disinfection of medical waste was necessary while 6 (6%) did not know. A greater proportion 61 (61%) of the respondents strongly agree that safe disposal of BMW was necessary in healthcare setup while 1(1%) strongly disagreed. Above half 56(56%) of the respondents strongly agreed that BSWM is a teamwork while 2 (2%) strongly disagreed. Also, 54 (54%) of the respondents strongly agreed that BSW management creates extra burden on routine work while 3(3%) strongly disagreed. A greater proportion 59 (59%) of the respondents strongly agreed that BMW management is a risk for transmission of any infectious disease while 3 (3%) strongly disagreed. Fifty-one (51%) of the respondents strongly agreed that segregation of hospital waste into different categories is time consuming while 9 (9%) disagreed. Also, 51(51%) of the respondents strongly agreed that PPE is a must while handling biomedical waste while 1(1%)disagreed.

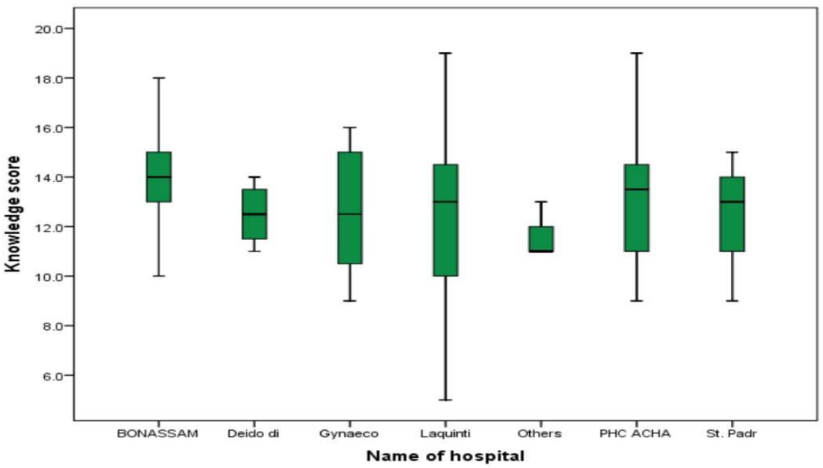


Fig. 2. Variation in the knowledge score of health personnel on BSWMP in the health facilities included in to the study

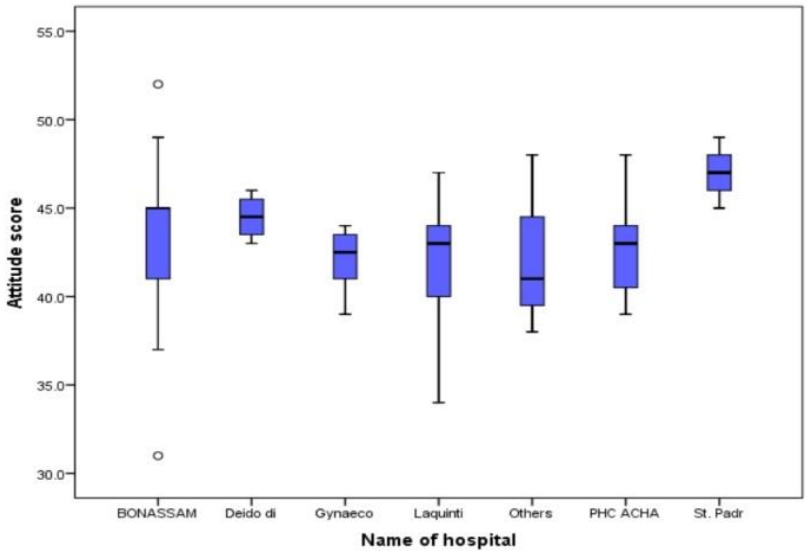


Fig. 3. Variation of the attitude scores of health personnel across the health facilities included in to the study

Regarding the attitude of health personnel towards BSWMP, 61 (61%) of the respondents strongly agreed that de-contamination and disinfection reduce infection while just 1 (1%) disagreed. Fifty-two (52%) of the respondents strongly agreed that use of colour code for segregation of waste is must while 2 (2%) disagreed. Also, 51 (51%) of the respondents strongly agreed that proper BMW management enhance the quality assurance of healthcare sectors while 1(1%) strongly disagreed. Above half, 55 (55%) of the respondents strongly agreed that upgradation of knowledge on BMW management is mandatory while 1 (1%) disagreed. Half, 50 (50%) of the respondents strongly agreed that it is good to disposed of biomedical waste in general waste dumping site while 5 (5%) strongly disagreed. More so, 51 (51%) of the respondents strongly agreed that it is vital to report all accidental exposures to blood and body fluids at the workplace while 1 (1%) strongly disagreed (Table 2).

The practice of health personnel on BSWMP was scored on a total score of 20. The mean score was 14.150 ± 4.471. The maximum score was 20, minimum score of 2 (range=18) and a median score of 15.0. Most, 77 (77%) of the respondents had a good practice on BSWM while 23 (23%) had a poor practice on BSWM (Fig. 4).

Fig. 4 presents the **v**ariation of the BSWM practice scores among the respondents in the health facilities included in to the study. Laquintinie hospital had the highest variation in practice scores among its health personnel with the lowest and highest score coming from this health facility while Deido District Hospital had the least variation in the practice score among its health personnel.

Regarding the health personnel practice on BSWM, 63 (63.3%) of the respondents said biomedical waste disposal charts are in different departments of their hospital while 9 (9.1%) said they never noticed if biomedical waste disposal charts are in different departments of their hospital. Most, 71 (71%) of the respondents said their hospital follow the guidelines given by Ministry of Heath for BMW management while 14 (14%) said the do not know. Majority, 71 (71%) of the respondents that their hospital adhere to the infection control policy while handling waste while 7 (7%) did not know. A greater proportion 68 (68%) of the respondents said their hospital use personal protective equipment while handling biomedical wastes while 10 (10%) did not know. Also 74(74%) of the respondents said their hospital discard all personal protective equipment after handling biomedical wastes while 9 (9%) did not know. More so, 72 (72%) of the respondents said their hospital follow color-coding of containers according to the type of wastes for disposing BMW while 8 (8%) did not know. Most 75 (75 %) of the respondents said their hospital follow the policies separating BMW as non-hazardous, hazardous, and sharp waste in segregation while 9 (9%) did not know. Seventy (70%) of the respondents said their hospital maintain BMW records while 8 (8%) did not know. Above half, 60 (60%) of the respondents said waste management training had been set up for the hospital staff while 12 (12%) did not know. Majority, 73 (73%) of the respondents said their hospital treat waste before disposal while 9 (9%) did not know.

With regards to the Health personnel practice on BSWMP, 72 (72%) of the respondents said there is a landfill in their facility while 7 (7%) did not know. Most, 80 (80%) of the respondents said they have an incinerator in their health facility while 5 (5%) did not know. A greater proportion 62 (62%) of the respondents said national waste management plan were available in their facilities while 14 (14%) did not know. Most, 75 (75%) of the respondents said waste management plan was available in their health facility while 7 (7%) said they don't know. Sixty-three (63%) of the respondents said their hospital waste was treated off-site while 8 (8%) did not know. Also, 79 (79%) of the respondents said members of staff were reminded about sorting waste while 7 (7%) did not know. More so, 77 (77%) of the respondents said bags that have been collected were replaced immediately with new bags while 8 (8%) did not know. Furthermore, 73 (73%) of the respondents said there was a means of conveyance/transport reserved for medical waste while 6 (6%) of them did not know. A greater proportion 61 (61%) of the respondents reported that there was a separate means used for each type of waste in the health facility while 12 (12%) did not know. Most, 76 (76%) of the respondents said there was particular attention paid to he treatment of sharps and highly infectious wastes while 6 (6%) did not know (Table 3).

Table 2. Attitude of health personnel toward BSWMP

Variable	Categories	Frequency (n)	Percentage (%)
De-contamination and disinfection reduce the infection	Agree	46	46
	Disagree	2	2
	Neutral	30	30
	Strongly agree	122	122
	Total	**200**	**200**
Use of colour code for segregation of waste is must	Agree	70	70
	Disagree	4	4
	Neutral	22	22
	Strongly agree	104	104
	Total	**200**	**200**
Proper BMW management enhance the quality assurance of healthcare sectors	Agree	70	70
	Disagree	6	6
	Neutral	20	20
	Strongly Agree	102	102
	Strongly disagree	2	2
	Total	**200**	**200**
Upgradation of knowledge on BMW management is mandatory	Agree	64	64
	Disagree	2	2
	Neutral	24	24
	Strongly agree	110	110
	Total	**200**	**200**
It is good to disposed of biomedical waste in general waste dumping site	Agree	50	50
	Disagree	20	20
	Neutral	20	20
	Strongly Agree	100	100
	Strongly disagree	10	10
	Total	**200**	**200**
It is vital to report all accidental exposures to blood and body fluids at the workplace	Agree	66	66
	Disagree	4	4
	Neutral	26	26
	Strongly Agree	102	102
	Strongly disagree	2	2
	Total	**200**	**200**

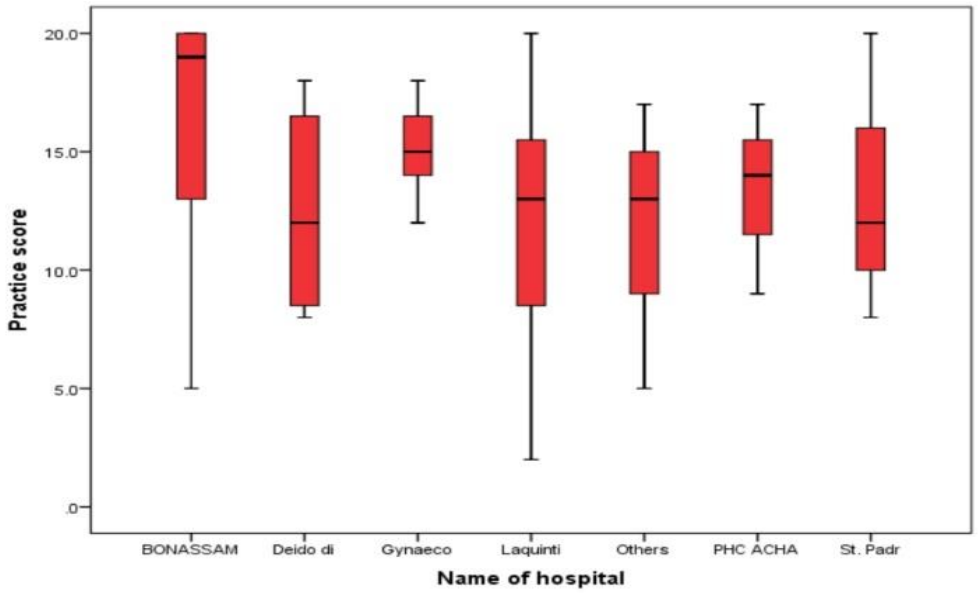


Fig. 4. Variation of the BSWM practice scores across the health facilities included in to the study

Table 3. Health personnel practice on BSWMP

Variable	Categories	Frequency (n)	Percentage (%)
Availability of landfill in the vicinity	I don't know	14	14
	No	42	42
	Yes	144	144
	Total	**200**	**200**
Availability of an incinerator in this health facility	I don't know	10	10
	No	30	30
	Yes	160	160
	Total	**200**	**200**
Availability of any national waste management plan available	I don't know	28	28
	No	48	48
	Yes	124	124
	Total	**200**	**200**
Waste management plan in the health facility	I don't know	14	14
	No	36	36
	Yes	150	150
	Total	**200**	**200**
Waste treated off-site	I don't know	16	16
	No	58	58
	Yes	126	126
	Total	**200**	**200**
Members of staff reminded about sorting waste	I don't know	14	14
	No	28	28
	Yes	158	158
	Total	**200**	**200**
Bags that have been collected are replaced immediately with new bags	I don't know	16	16
	No	30	30
	Yes	154	154
	Total	**200**	**200**
Means of conveyance/transport reserved for medical waste	I don't know	12	12
	No	42	42
	Yes	146	146
	Total	**200**	**200**
Separate means used for each type of waste	I don't know	24	24
	No	54	54
	Yes	122	122
	Total	**200**	**200**
Particular attention paid to the treatment of sharps and highly infectious wastes	I don't know	12	12
	No	36	36
	Yes	152	152
	Total	**200**	**200**

Table 4. Association between Practice of BSWM with knowledge and assessment of BSWMP

Variable	Categories	n	Practice				Chi-square	P-value
			Good	%	Poor	%		
Knowledge	Good	72	61	61	11	11	8.658	**0.003**
	Poor	28	16	16	12	12		
	Total	**100**	**77**	**77**	**23**	**23**		
Policy assessment	Good	74	60	60	14	14	2.677	0.102
	Poor	26	17	17	9	9		
	Total	**100**	**77**	**77**	**23**	**23**		

Table 4 presents the association between practice of BSWM and demographic characteristics of the health facilities included in to the study. There was a significant association between name of hospital (χ = 15.709, p=0.015) , location of hospital (χ = 15.063, p=0.012) and total number of beds per specialty (χ = 10.369, p=0.017) with demographic characteristics of the health facilities.

With regards to the association between Practice of BSWM with knowledge and

assessment of BSWMP, there was a significant association between practice on BSWM with assessment on BSWM and knowledge on BSWMP.

Table 4 presents the factors independently associated with the practice of BSWM. Persons that were aged 30-39years were 3.696 times more likely to have a good practice on BSWM compared to those that were aged 40-59 years (AOR= 3.696, CI= 0.582-6.551, p= 0.041). Health personnel that had a good knowledge on BSWM were 4.399 times more likely to have a good practice on BSWM compared to those that had a poor knowledge on BSWM (AOR= 4.399, CI= 1.583-12.228, p=0.005).

4. DISCUSSION

The study shows that the BWs in the selected healthcare facilities are affected by a number of individual-hospital characteristics such as the number of beds, the type of the hospital/healthcare provider, the services they provide, the number of annual inpatients, the days of staying, the number of scheduled surgeries, the existence of special units (e.g., Intensive Care Unit), and the total number of employees. Some of these factors are also mentioned and confirmed in various studies from different countries such as Taiwan, Jordan, Kuwait, India, and Nigeria, as well as from Greece, such as the type of the hospital, the number of inpatients–outpatients, etc. It is very possible that additional factors may significantly affect the production of biomedical waste, especially during the pandemic of COVID-19, where the HCWs' generation rates and qualities were increased dramatically. To continue, these factors that affect the waste produced, along with the financial impact, can help hospital managements/managers, officials at the governmental level, and the Cameroon's Ministry of Health to understand what needs to be altered and implemented in order to protect the environment, reduce hospital operational costs, and implement the necessary policies and action plan. With the proper actions, the amount could be reduced and reinvested in other areas of the healthcare sector.

The number of beds in each hospital affects the quantities and costs of infectious waste management differently and according to the type of structure. In small hospitals, waste management costs more as the number of beds increases, but in other hospitals, the rate of increase is much lower. The hospitalized patients also have a positive correlation with both management costs and quantities of hazardous waste generated in each hospital, but the days of hospitalization have a very small but negative effect on them. Likewise, the number of scheduled surgeries have a slightly negative effect on the quantities of waste generated. Finally, the number of staff working in hospitals have a statistically significant positive effect on costs and quantities. It will be of great significance to compare the current results and findings with a future study, using up-to-date data from the healthcare sector. The rising of awareness and increasing of knowledge regarding biomedical waste management, health, safety and environmental issues, and infectious waste risks should be performed by the hospital staff (especially doctors and nurses) via specialized training programs, posters, applied policies, lectures, etc. This will lead to the reduction of biomedical waste and the better segregation of regulated medical waste, consequently leading to the reduction of the volume and respective costs.This enables the central administration of the Ministry of Health and of each hospital individually to identify deviations in costs and quantities of infectious waste, enabling preparation in terms of budgeting, evaluation, and improvement in the areas that are needed each time for better management in terms of sustainability, economics, and the environment.

In addition, these two prediction models can be used by governmental bodies and authorities in order to change the current status and improve the weaknesses, vulnerabilities, and the possible dysfunctions of the public healthcare sector.

Thus, the following proposed actions have to be taken into consideration for implementation in the Douala healthcare sector so as to transform it into a sustainable one:

- A proper and customize sustainable waste management system should exist and function;
- Proper training regarding the waste management and the occupational safety of healthcare professionals;

- The implementation of a waste management policy and a customized Standard Operational Procedure (SOP);
- A review of the current legislation and relating policymaking;
- The implementation of new medical waste treatment technologies;
- Recycling of materials;
- The need for standardized and mutually accepted guidelines in national and international level of HCWs;
- A minimization of the costs and related risks from biomedical wastes.

Study results show that most of the respondents (over 70%) do not use code-colored waste bins at all. This may be attributable to unavailability of these bins in this hospital, as well as poor training on sustainable healthcare waste management, which has been identified in literature [28] (Furthermore, unavailability of color-coded bins may be the reason for the non-significant relationship between occupation and use of code-colored waste bins. Results also show that more than half (about 60%) of the study respondents segregate their biomedical waste, which was statistically significant in relation with occupation. Segregation of waste is importance to sustainable HCW management as posited by [29]. Regression results on predicting whether or not workers have been trained on sustainable biomedical waste management based on respondents' occupation, years of experience and waste disposal methods was statistically significant, indicating that the variables are a good fit in the model. This is in line with [30] logistic model for predicting waste management practices. Model parameter estimates indicates that "occupation" was statistically significant implying that being trained on sustainable HCW management may depend on designation in the hospital [31]. This is in line with the findings of [32] on knowledge variation on sustainable HCW management. Also, "11-15 years" under years of experience was statistically significant. This is because the odds of workers with 11-15 years' experience being trained on sustainable HCW management is 3.580 times more than those with 1 year experience, as shown in Table 4. This finding could also indicate that imbibing sustainable biomedical wastes management practices increases with higher experience in the hospital. Furthermore, communal bin disposal of biomedical wastes was the only statistically significant category under disposal method, indicating that waste disposal may be lacking in terms of sustainable practices. Sepetis; [33] also identified biomedical wastes disposal in open dumps among health workers in Saudi Arabia, attributable to poor sustainable waste training and lack of regulatory frameworks [34].

5. CONCLUSION

The study has assessed sustainable healthcare waste (HCW) management practices among hospital workers in the City of Douala, by predicting the likelihood of being trained on sustainable management and also determining the dimensions of prevalent biomedical wastes. Results indicate that code-colored bins are not available in the hospital studied. Furthermore, many workers in the healthcare facility studied segregate HCW generated, depending on occupation in the hospital. Furthermore, regression model for predicting being trained on sustainable biomedical waste management statistically significant, indicating that occupation, experience and waste disposal method were fitting variables in the model. Also, PCA of eight variables on prevalent HCWs in the hospital studied pointed towards a two-dimension structure: low risk wastes that do not require treatment and special waste needing treatment and cautious management. Based on the study's key findings, it recommended that code- colored waste bins are provided in various sections of the hospital. This will go a long way in ensuring that waste is separated at source, thereby fostering sustainable biomedical waste management. More training activities using a more practical approach to sustainable biomedical waste management should be provided. This is because practical trainings are more explicit in imbibing the principles of sustainable biomedical waste management. Also, more effort should be made in providing multi-purpose HCW treatment systems in large hospitals. These treatment systems can integrate recycling of general waste and incineration of special waste which may be hazardous when disposed in communal bins and dump sites [35].

7. LIMITATIONS OF THE STUDY

It is an imperative need to extend the scope of this study into all the HCFs in Douala healthcare

sector in order to investigate the similarities and differences between them, as well as their correlations.

CONSENT

Written informed consent was obtained from each participant before their enrollment into the study.

ETHICAL APPROVAL

All authors hereby declare that all experiments/questionnaires have been examined and approved by the Institutional Ethics Committee for Research on Human Health of the University of Douala, regional ethical committee approvals. The Institutional Ethics Committee for Research on Human Health of the University of Douala Project number is 3491/IEC-UD/01/2023/T.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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