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Hospital Waste Management at the Provincial Hospital and the Notre Dame des Apôtres Hospital of Sarh, Chad

Lévy Manna Agdet[1], Ngoussou Mbailaou[1], Jean Beinde[1], Malato Ganda Adoum[1], Mbété Adoum Poutoudet[2], Doloum Gomoung[1*]

[1]Faculty of Science and Technology, University of Sarh, Sarh, Tchad
[2]Faculty of Arts and Humanities, University of Sarh, Sarh, Tchad
Email: *ggomoung@gmail.com

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Abstract

In order to improve environmental and individual health and make aware that poor management of biomedical waste is a vector for the spread of many diseases, a study was conducted on the management of hospital waste in two main reference health structures, the Provincial Hospital (HP) and the Hospital of Our Lady of the Apostles (HNDA) of Sarh. The general objective of this study is to contribute to the reduction of environmental pollution through the management of biomedical waste. More specifically, it is to: 1) identify the sources of the waste, 2) sort and classify the waste by their categories, 3) assess the quality of the water in the yard of each health facility involved. The study was based on surveys, documentary research and physico-chemical and bacteriological analyses of the water in the two hospitals. The results of this work made it possible to identify that the DBM management system remains inadequate and that neither of these two reference health facilities in the province had a hospital waste management plan or produced waste management activity reports. 96% of the medical and paramedical staff interviewed confirmed that biomedical waste was sorted, 32% of the medical and paramedical staff confirmed that the waste treatment program was not followed before disposal, and 16% were not informed about hospital waste management. All the support staff for hygiene and sanitation services in the two health facilities are illiterate. In terms of vaccinations, 100% of health care staff and waste managers at the hospitals are not vaccinated against hepatitis or tetanus serum (TSS). The physicochemical and bacteriological analyses of the water showed the poor quality of these different waters, with the presence of germs indicating pollution.

Keywords

Hospital Waste, Biomedical Waste, Management, Environment,

Water and Pollution

1. Introduction

Hospitals are major producers of waste from a variety of sources. Healthcare generates waste that constitutes a reservoir of potentially dangerous micro-organisms, likely to infect healthcare workers and the general public (Mokoko et al., 2018; Chettou & Abidabd, 2012). Safe medical waste management practices are also based on the United Nations (UN) Sustainable Development Goals (SDGs), notably Goal (3) on health, Goal (6) on safe water management and sanitation, and Goal (12) on sustainable consumption and production (PGDBM, 2020). A 2002 WHO survey of 22 developing countries showed that between 18% and 64% of healthcare facilities do not dispose of their waste properly. Injections with contaminated syringes are responsible for 21 million cases of hepatitis B, 2 million cases of hepatitis C and 260000 cases of HIV AIDS (Belaloui & Frih, 2019). When Biomedical Waste (BMW) is deposited in uncontrolled landfills to which the public has easy access, children are particularly exposed to contact with infectious waste (Kizerbo, 2011).

In Chad, the annual production of biomedical waste (DBM) is around 15,974 m^3 (Mbaye, 2018). However, there is no sectoral policy of formalized procedures for biomedical waste (DBM) management. The national health policy document (PNS) does not give high priority to the management of DBM (Mbaye, 2018). The country does have laws, but they are not applied (Law n˚ 014/PR/98).

The rapid development of urbanization, the result of strong population growth, has created living conditions that are unfavorable to health (Eloundi & Djenadek, 2016). The inappropriate management of biomedical waste in most developing countries constitutes a risk for healthcare staff and the population attending health facilities (Mbaye, 2018). Indeed, a WHO report reveals that in 2012, the environment was responsible for 12.6 million deaths per year, or 23% of global mortality. This figure is a real wake-up call on the issues of preserving our environment (Mathilde, 2019).

The Provincial Hospital and the Notre Dame des Apôtres Hospital in the commune of Sarh are the referral hospitals for the entire Moyen Chari Province, and are the largest health facilities. As such, they provide high-level care and receive complicated emergency cases from the interior and other provinces. For all these reasons, they need to develop effective hospital waste management strategies to avoid the health and environmental damage associated with poor DBM management. Is there a DBM management structure in these two facilities? These are the reasons behind the choice of these two research sites. The overall objective of this research is to contribute to the reduction of environmental pollution through the management of biomedical waste (MBW), and more specifically to: 1) Identify the sources of biomedical waste; 2) Sort and categorize MBW; 3) Assess water quality in the courtyard of each health facility concerned.

2. Materials and Methods

2.1. Hardware

2.1.1. Presentation of the Study Area

The town of Sarh lies between latitudes 9˚13 and 9˚10 north and longitudes 18˚23 and 18˚25 east.

The Sarh provincial hospital (HP), in the 2nd arrondissement, is located between latitude 9˚08 North and longitude 18˚23 East, while the Notre Dame des Apôtres Hospital (private, denominational structure), in the 6th arrondissement, is located between latitude 9˚74 North and longitude 18˚23 East.

The Moyen-Chari Province is generally flat. Its pedology is made up of three types of soil (hydromorphic soil, leached ferralitic soils, and deep sandy red soils), which are characteristic of the Sudanian zone (Monodji, 2020). The climate in the town of Sarh is tropical and humid, with two seasons: a rainy season from April to October and a dry season from November to March. Rainfall averages between 800 and 1200 mm per year.

2.1.2. The Equipment Used to Manage DBM

Black bag for hazardous waste, yellow bag for contaminated waste, yellow container for anatomical waste and PCT, gloves and mask for waste collection.

2.2. Methods

Field Survey

The study was based on a survey and participation in waste collection. Data collection was carried out using a pre-established questionnaire (closed, open and semi-open questions) during an interview. These data were supplemented by direct observations. Sampling was clustered and random. The sample size was 30 agents, made up of medical and paramedical staff, as well as personnel in charge of collecting and processing DBM from these two health facilities in the town of Sarh, according to their size, with 20 agents surveyed at the Provincial Hospital and 10 at the Notre Dame des Apôtres Hospital.

A well-considered choice of departments was made based on the intensity of medical activities and the diversity and specificity of the discharges produced in these departments. (Table 1)

Table 1. Different services and number of people surveyed at HP and HNDA.

Services Surveyed	Number of Persons	Percentage
Hygiene and sanitation	06	20%
Pediatrics	07	23.34%
Maternity ward	05	16.66%
Laboratory	06	20%
Emergency pavilions	06	20%
Total	**30**	**100%**

2.3. Data Analysis and Processing

After data collection, data processing and analysis were carried out using Microsoft Excel 2013 and IBM SPSS version 23.0.

2.3.1. Physico-Chemical and Bacteriological Analyses

Analyses of physico-chemical and bacteriological parameters are carried out in the laboratory using specific electronic equipment, such as the pH meter, conductivity meter, turbidity meter and DR3900 spectrophotometer. All these instruments display results in numerical values.

2.3.2. Sample Storage and Conditioning

Bottles were kept cool, protected from light and dust, and transported to the laboratory for analysis on the same day.

2.3.3. Procedure for Bacteriological Analysis

The following steps were taken:

Check the top vessel for leaks, and fill the top vessel with the water to be analyzed up to the 100 ml mark. Set up the manual vacuum pump, filter by creating a vacuum, remove the filter using flame-disinfected forceps and place it on the appropriate medium in the plate without leaving any air bubbles between the filter and the culture medium so that all the filter is in contact with the culture medium. Label and store the plates in the dish and incubate at 37˚C - 44˚C.

2.3.4. How to Prepare the Culture Medium

The solution used to prepare the culture medium is based on distilled water and Laury sulfate. The amount of reagent used for 20 mL is 1.5 grams. Once the solution is prepared, we use the syringe to draw the solution and soak the membrane support. And the sample must have two media, one of which will be subjected to 37˚C for 24 h for total coliforms, and the other to 44˚C for faecal coliforms and *Escherichia coli.* The enterococci medium follows the same process, and the quantity we use is 42 grams per 100 mL. A medium for the detection of fecal *Enterococci* is made at 37˚C for 48 h.

2.3.5. Incubation

Incubation lasts 24 hours for coliforms and *Escherichia coli*, then 48 hours for fecal *Enterococci* in the two compartments of the device.

2.3.6. Reading the Results

After the incubation time has expired, the presence of bacteria is characterized by different colors, which we can read with the naked eye or a magnifying glass: total coliforms are characterized by a yellow color, fecal Enterococci by a brown, red or pink color; *Escherichia coli* by a blue-dark to violet color and fecal coliforms by a yellow or pink color. Bacteria are counted on the membrane filter, and when their density on the membrane is very high, we estimate that the number of bacteria is greater than 100.

3. Results and Discussion

The various surveys and data collected from medical, paramedical and waste management staff at HP and HNDA enabled us to gather information (data), the processing of which provided results presented in graphical or tabular form according to the chronology of the research questions formulated, followed by a discussion.

3.1. Staff Professional Experience

Table 2 shows the number of years of professional experience in the field. The majority of respondents are young. They have insufficient professional seniority (56.7%), which does not enable them to master hospital waste management (HWM) practices. At HP, the medical and paramedical staff surveyed have more than twenty (20) years of seniority. This seniority should explain their experience in biomedical waste management and disposal. The work of Saizoumoun et al. (2013) in Benin gave a result contrary to our findings. According to them, 50% of the different socio-professional categories surveyed were care assistants, all equally experienced. On the other hand, the professional seniority of biomedical waste managers at HNDA, ranging between [10 - 20 years], is sufficient for the mastery of their practices.

Table 2. Surveyed socio-professional categories and their seniority.

Number of years of service	HP			HNDA			Number of years of service	HP
	Pers med	Pers para		Pers med	Pers para			
[0 - 10 years]	05	06	02	01	02	01	17	56.7
[10 - 20 years]	02	02	0	03	0	02	09	30
[20 Years and older]	02	01	0	01	0	0	04	13.3
Total	**09**	**09**	**02**	**05**	**02**	**03**	**30**	**100**

With pers med = medical staff, pers para = paramedical staff.

3.2. HP and HNDA Staff Specialties and Numbers

The specialties and numbers of personnel in our study area are shown in **Table 3** and **Table 4**.

In our interviews with the various people in charge of our study area, we identified various specialties and a large number of staff (**Table 2** and **Table 3**). Today, these hospitals serve as reference health structures in the province of Moyen-Chari, as well as in neighbouring provinces. With a capacity of around 300 beds, they generate a large amount of hospital waste, which undoubtedly needs to be properly managed to protect human health and the environment.

3.3. Hygiene and Sanitation Unit

HP and HNDA did not have a hospital waste management plan, yet each has a hygiene and sanitation manager. The results are comparable to those of the

Table 3. Number of HP staff and their specialties.

Specialties	Workforce
Medical specialists	03
General practitioners	12
Senior pharmacy technicians	02
Medical and paramedical staff	52
Senior laboratory technicians	14
Administrative staff	07
Contract staff	43
Total	**133**

Table 4. HNDA staff and their specialties.

Specialties	Workforce
Medical specialists	0
General practitioners	02
Nutrition Physician	01
Nurses (IDE, ATS)	16
Senior laboratory technicians	02
Midwives	04
Nutritionist	01
Support staff	15
Administrative staff	03
Total	**44**

WHO's hospital waste assessment study (WHO, 2005) in 22 developing countries, including Chad, showed that 18% to 64% of health facilities did not apply appropriate methods for disposing of hospital waste, as cited by Ndié and Nguendo (2016), and corroborate those of Cheikh (2003), who states that in Senegal, several health facilities do not have an appropriate management plan to ensure proper management of GDBM. This state of affairs can be explained by the fact that those in charge of health facilities and hygiene and sanitation units were unaware of hospital waste management standards, hence the scarcity of these essential tools in our study sites. The hygiene and sanitation unit is responsible for promoting hospital hygiene, implementing hygiene policies and coordinating related activities.

Article 6 of Joint Order N˚054/PR/MEENP/SG/18 stipulates that generators of MBW are required to set up an internal management system and plan, which includes the designation of a unit responsible for this waste, including source separation, packaging, storage, collection, transport, treatment and disposal.

3.4. Biomedical Waste Sorting

With regard to sorting, the results showed that various categories of waste are produced: waste assimilated to household refuse (DAOM), sharps waste, waste from infectious risk care activities (DASRI), anatomical waste, pharmaceutical waste and x-ray films produced exclusively in the radiology department.

Considering that sorting is the best way to reduce the volume of hazardous waste requiring special treatment during work at the study sites, we observed the following practices:

- The use of rigid, heavy-duty yellow containers for sharps waste at both hospitals;
- The use of ordinary rubbish baskets instead of black plastic bags for household waste or waste assimilated to household waste (DAOM) and contaminated waste (compressed cotton, etc.) at HP.

The use of 25 l black drums for infectious, contaminated waste and wastebaskets for miscellaneous packaging at HNDA (**Figure 1**).

Figure 1. Waste bins and safety boxes used at HNDA.

Figure 2. Location of safety boxes and a waste garbage can in the biochemistry and serology unit at HP.

In both hospitals, sorting standards are not always respected or taken into account by staff who generate waste at source. As a result of these observations, at HP, some care workers sometimes mix empty vials with contaminated waste. **Figure 2** shows that at Hôpital Provincial de Sarh, 17 out of 18 medical and paramedical staff surveyed complied with biomedical waste sorting, while at Hôpital Notre

Dame des Apôtres, 100% of those surveyed complied with biomedical waste sorting.

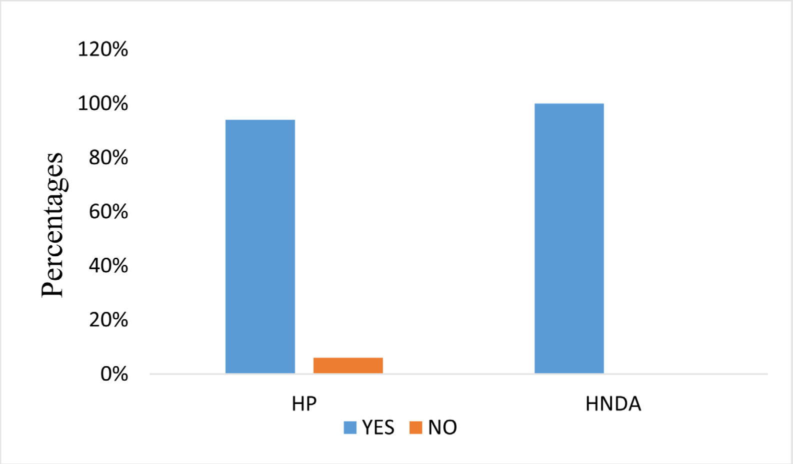

Figure 3. Percentage of care staff who respect sorting.

The results showed that twenty (20) medical and paramedical staff from the two hospitals, 80% of those surveyed, affirmed the existence of sorting at source (**Figure 2** and **Figure 3**). These results are similar to those obtained by Alidou (2020), Mokoko et al. (2018) and Ndié and Ngeundo (2016), who confirm that many of the people surveyed affirmed the existence of DBM sorting respectively in the departmental hospital center of Natitingou in Benin and in the CHU of Brazzaville in Congo, and in the reference health structures of the North Cameroon region. It should be noted that all the services surveyed sorted waste at the source, but this sorting was inadequate and did not comply with WHO recommendations. It was limited to the separation of sharps, HIW and highly infectious waste. According to the WHO, the safe management of MSW consists of maintaining their separation during transport, storage, treatment and disposal (WHO, 2017a).

This operation ensures that the waste is disposed of properly, thus preserving staff safety and reducing environmental impact. With regard to the concept of sorting, 36% of those surveyed stated that sorting waste from care activities is difficult. This result explains the care staff's careless management of biomedical waste, which encourages the mixing of different categories of waste, resulting in accidents for the staff responsible for collecting and transporting biomedical waste. A study on the Management and treatment of hospital waste, carried out by Seid and Toutha in 2017 at Lakhdaria Hospital in Algeria, also showed that the biomedical waste sorting operation is neglected by care staff.

Figure 4 above shows that, on average, 82% of respondents claimed to respect sorting in both hospitals. The results are contrary to those obtained by Ndié and Nguendo (2016) who state that in North Cameroon, 91.70% of health facility managers said that staff had not mastered the system or the convention of color-coding buckets/bags. 22% and 14% respectively at HP and HNDA, i.e., 18% of respondents, did not respect sorting. The results corroborate the work of Hinson et al. (2016) in Togo, who made the same finding. The results are in line with those obtained by Dehimi et al. (2019), who report that 27% of nursing staff do not respect the color code at the Etablissement Hospitalier Spécialisé (EHS) Mère et Enfant in Algeria. With regard to compliance with specific containers, only 22% of nursing staff at HP did not comply (**Figure 4**). The results obtained are encouraging in comparison with the research work of Mbog Mbog et al. (2020), who found that in Cameroon (North, Adamaoua, East and North-West), the color coding system was not effective in any of the health facilities. The color-coding system was not applied, and none of the departments surveyed used it to sort waste. However, this coding system enables the identification and separation of DBM, significantly reduces the quantity of waste requiring special treatment and the cost of treating it, and also considerably reduces the risk of infection for staff handling DBM. Similar results have been obtained by Alidou (2020) in Benin, Azhar (2018) in Senegal, and WHO (2004). With regard to the materials and equipment used for sorting DBM, the staff who carry out DBM sorting are under-equipped with working materials and protective equipment. This could have harmful consequences. This situation is hardly conducive to the implementation of good DBM practices.

With regard to waste directed into unlabeled garbage cans (**Figure 5**), above,

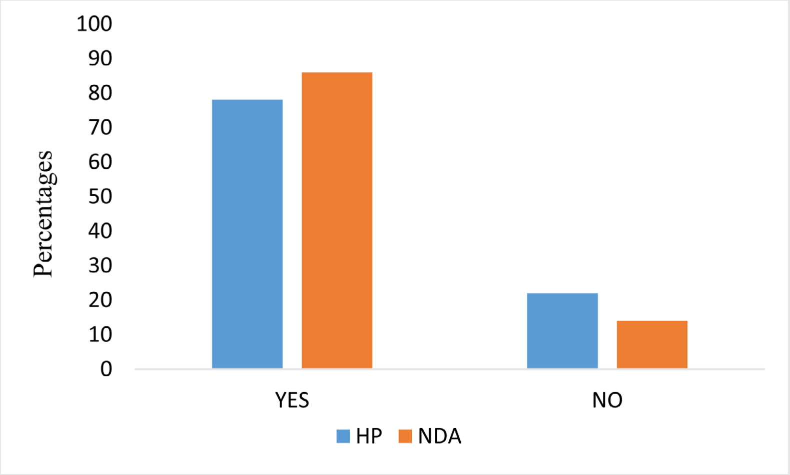

Figure 4. Percentage of medical and paramedical staff respecting sorting.

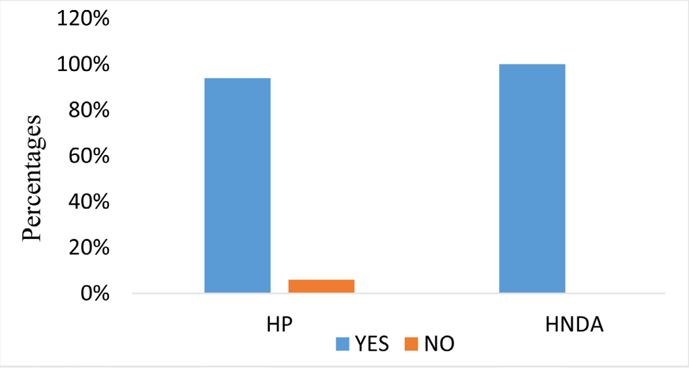

Figure 5. Staff at two hospitals, disposing of waste in special containers.

19% of people in the two hospitals surveyed said that this could be the cause of accidents during biomedical waste collection by the staff in charge of this waste. Chettou and Abidabd (2012) at the CHU Batna in Algeria showed that 80% of medical staff felt that misdirected waste could be the cause of many accidents. According to the biomedical waste management guide in Burkina Faso, the various garbage bags and safety boxes collected are then labeled and taken to the storage room (Anonymous, 2017). However, only the glove and mask (muffler) are the personal protective equipment (PPE) possessed by the agents in charge of collection, transport and disposal at HP and HNDA de Sarh to the storage locations. This result differs little from the work Hinson et al. (2016) and Aguèmon et al. (2014), who found in their surveys that only the glove was personal protective equipment that agents had for the collection, transport and disposal of DBM in Benin. According to (Mathilde, 2019), efficient sorting of hospital waste reduces health and environmental risks for waste categorized as hazardous. The results in **Figure 6** show that 58% of respondents at HNDA versus only 44% at HP comply with weekly sorting. This largely explains why sorting is neglected in the study area.

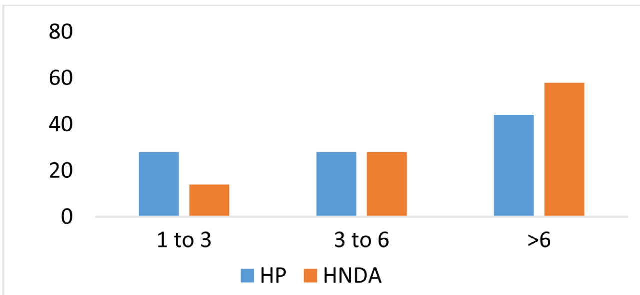

Figure 6. Number and percentage of people who sort by week.

Table 5. Percentage of hospital waste collection rate at the two hospitals.

Rhythm	HP	HNDA	Total	Percentage
Once and day	14	6	20	80%
Once and week	4	1	5	20%
Total	18	7	25	100%

The results in **Table 5** show that 80% of the medical and paramedical staff surveyed in the two hospitals claim to have an idea of the frequency of biomedical waste collection, while 20% are unaware of the application of this operation according to standards. These results corroborate those obtained by Ndiaye et al. (2020). The latter noted that waste collection should be carried out on a daily basis, but in some departments, the person in charge of transporting the waste passes by every other day. Similarly, proper collection of DBM hardly allows waste to accumulate at the place where it is produced (Anonymous, 2017). This requires daily collection. The results are contrary to those of WHO (2017a) on the safe management of medical waste, which indicates that the collection of pathological and infectious waste is carried out at least once a day.

3.5. Biomedical Waste Storage

The results on storage show that 92% (**Table 6**) of respondents in both hospitals confirm that biomedical waste is stored in special areas away from patients. These results confirm the existence of a special DBM storage area at HNDA. The results of our research show that only the HNDA had a storage room that more or less complied with standards, except for the fact that it had no approved garbage cans for storing waste from healthcare activities at risk of infection (DASRI), apart from the safety boxes for PCT (**Figure 6**). The HP, on the other hand, had garbage cans that complied with standards, but lacked an appropriate room for waste storage. These garbage cans are displayed along the corridors of the hospital wards (**Figure 8**). Metal waste is stored in an appropriate room (**Figure 7**). These results are similar to those obtained by Ndiaye et al. (2020) in Dakar, Senegal. In their study, only HPD out of the five hospitals surveyed in Senegal had an area meeting standards. These findings were noted by Benhaddou et al. (2019) in Algeria at the Sidi Bel Abbes health sectors, and among the facilities surveyed, 60% had only intermediate storage areas. Cheikh (2003) made the same observation at the Ziguinchor Regional Hospital (CHR) in Senegal, where garbage cans were displayed near offices or waiting rooms, along corridors and in the courtyard. This unhygienic and unsanitary practice represents an infectious risk for nursing staff, patients and visitors.

Table 6. Respondents' opinions on where to store waste away from patients.

	HP	HNDA	Total	Percentage
Yes	16	07	23	92%
No	02	00	02	08%
Total	18	07	25	100%

The reduction of metal waste is generally done by the welding department to make other pieces of furniture such as chairs, tables, cupboards, beds etc.

3.6. Type of Most Hazardous Waste

With regard to the most hazardous type of waste, an analysis of two health facilities showed that needles were the most hazardous waste (88%), followed by compresses (08%) (**Figure 7**). At HNDA, medical and paramedical staff recognized the needle as the only and most hazardous waste (**Table 7**).

Similar results were obtained by WHO (2006) and Seid and Toutha (2017). The latter noted respectively as a result of their work that sharp objects and, more specifically, needles are considered the most dangerous category of medical waste for health and collection workers in general, due to the risk of needle-stick injuries representing a high risk of infection. Soiled compresses are one of the most

Table 7. Type of most hazardous waste.

Waste category	HP	HNDA	Total
Needle	15	07	22
Compress	02	00	02
Packaging	01	00	01

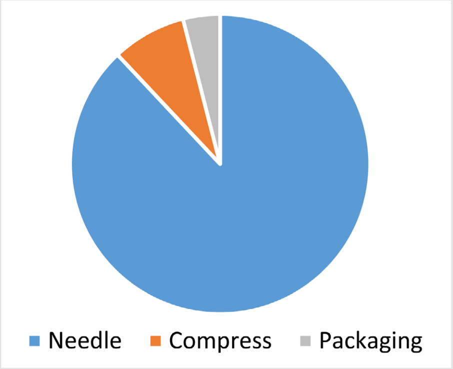

Figure 7. Percentage of nursing staff with the most hazardous type of waste.

infectious or contaminated types of waste. Four percent (04%) of staff at the Provincial Hospital considered packaging to be hazardous waste, which means that they are unable to distinguish between the different types of biomedical waste. These results are contrary to those obtained by the WHO (2005), which declares that packaging is part of non-hazardous waste, and is therefore treated as household waste (HHW). These results are in line with those listed in Chad's Plan de Gestion des Déchets Biomédicaux (PGDBM, 2020) in the Projet de Renforcement de Performance du Système de Santé (PRPSS), which covers eight (08) provinces and considers TPD to be one of the most hazardous categories of MBD produced by healthcare establishments. These findings are similar to those of WHO (2017b), which notes that sharp objects and, above all, needles are considered the most hazardous category of medical care waste for health workers, waste managers, due to the risk of needle-stick injuries with a high risk of infection.

Whether during care or vaccination, injections are responsible for the production of most infectious sharps. It is vital that infectious sharps are stored in resistant containers, disinfected and destroyed to ensure the safety of workers, and more broadly, the whole community.

3.7. Existence of a DBM Processing Program

Of the medical and paramedical staff surveyed, 100% at HNDA and 55.56% at HP confirmed the existence of a treatment program at their respective facilities. Overall, 68% agreed with the existence of a treatment program for DBM prior to disposal in both establishments, compared with 32%. Paradoxically, these respondents confirmed 100% compliance with the biomedical waste treatment program (Table 8). It is clear from this result that the respondents either answered the question without understanding it, or did not have enough information on biomedical waste management. According to field observations, this circuit was not known by all personnel involved in the management of biomedical waste, and even less so by the staff in charge of incineration. In addition, no health facility treats waste prior to disposal or destruction. In their study of hospital waste management in referral health facilities in North Cameroon, Ndié and Ngeundo (2016) made relatively the same finding. Of the 12 hospitals in their study area, none treated its waste before disposal. Our work also revealed that 16% of nursing staff questioned were uninformed about hospital waste management, unaware of the waste management circuit and exposing collection agents to sharps accidents, which cause infections. **Figure 7** below shows the percentage of nursing staff who have no information on the management of healthcare waste.

Figure 8. Representation of nursing staff who do not have information on waste management.

Table 8. Compliance with the DBM treatment program at HP and HNDA de Sarh.

	HP	HNDA	Total
Yes	18	07	25
No	00	00	00
Percentage	100%	100%	100%

The research also found that, at HP, 100% of staff in charge of waste management confirmed that waste treatment did not meet standards, compared with 33.3% at HNDA. Of all the staff surveyed, 60% stated that DBM treatment standards were not respected (**Figure 8**). This explains why staff have not mastered the concept and skills of correctly managing DBM, which exposes them to infections of all kinds. As a result, awareness-raising and training initiatives by those responsible for hospital waste management remain inadequate.

Regarding the wastewater treatment plant for liquid waste, only HP has had a plant since the 70s, when the hospital was built. It operates at a slow pace (two out of four turners are working). This waste is treated with chlorine whenever the treatment volume is reached, before being discharged into the Chari River (**Figure 9**). However, we are well aware that uncontrolled chlorine dosing can pollute the river water, leading inevitably to the proliferation of resistant micro-organisms and, consequently, exposing local residents to the risk of infection.

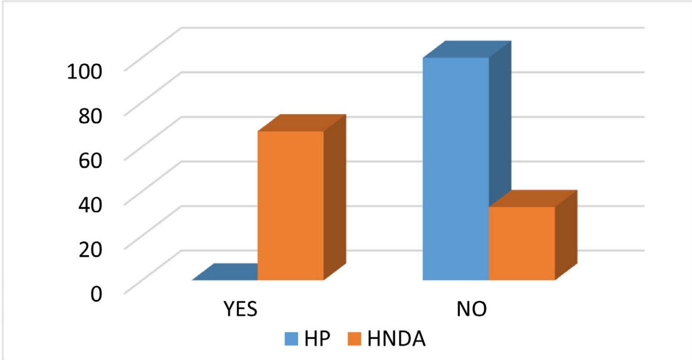

Figure 9. Processing of waste according to standards by DBM management staff.

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3.8. Level of Training of DBM Management Personnel

In both health facilities, we counted five DBM collection and management agents, including two (02) at HP and three (03) at HNDA, for a hospital capacity of around three hundred beds. These results reflect the presence of unqualified management staff and poor management of hospital waste (HW) within each of the study facilities. Our work shows that 100% of all hospital waste management support staff are illiterate (**Table 9**). The results are superior to those obtained by Gaouaoui and Hamadi (2019) who worked on the management of waste assimilated to household refuse and waste from care activities at infectious risk (DASRI) in Algeria. They state that 91% of DH management agents are illiterate, compared with only 9% who have a primary education level. However, the regulations governing hospital waste management call for qualified personnel trained in waste management activities. It also follows from this work that there is no biomedical waste collection service in the health establishments concerned.

Table 9. Level of training of DBM management personnel.

	HP	HNDA	TOTAL
Illiterate	2	3	5
Percentage	100 %	100%	100%

3.9. DBM Means of Transport

Among the means of transport used in our study establishments, our analyses showed that 100% of this transport is manual and the means used are buckets and wheelbarrows. In a similar study of hospitals in Mali by Sanogo et al. (2007), transport to storage sites entrusted to economic interest groups (EIGs) was done by manual handling, carts, and donkey carts. Manual transport is confirmed by the work of Benhaddou et al. (2019), who reported that manual transport of DBM in the commune of Sibi Bel Abbes in Algeria accounts for 90%. At the Ziguinchor Regional Hospital in Senegal, the study carried out by Cheikh (2003), provides an innovation according to which the transport of waste garbage cans must be carried out under high security, from the storage site to the disposal site, using honeycomb carts. These carts could be made inexpensively by local craftsmen.

3.10. Vaccination Coverage among DBM Management Staff

The results showed that at HP, 100% of these staff were neither vaccinated against TSS nor against the hepatitis B virus, whereas at HNDA, they were vaccinated against TSS and the hepatitis B virus, although biomedical waste management staff were aware of the infectious risk to which they were exposed. The results give an overall percentage of 40% of unvaccinated biomedical waste management staff. These results are similar to those of N'Zie et al. (2018), who showed that 40% of respondents were not vaccinated against the hepatitis B virus at Cocody University Hospital in Côte d'Ivoire in a study on biomedical waste management and biological risk. In the same vein, WHO (2005) also states that a person injured by a needle already used on an infected patient has a 30%, 1.8% and 0.3% chance, respectively, of being infected by the hepatitis B virus, the hepatitis C virus and HIV.

The results also show that 100% of biomedical waste managers at HNDA were victims of waste disposal-related accidents, compared with 0% at HP (**Figure 10**). Given the imminence of sharps injuries, it is important for hospital managers to ensure that all those involved in the management of medical waste are vaccinated. These risks faced by staff and agents in charge of waste collection and disposal are confirmed by the work of Gaouaoui and Hamadi (2019), who in a similar study suggested that these risks are emotional and traumatic.

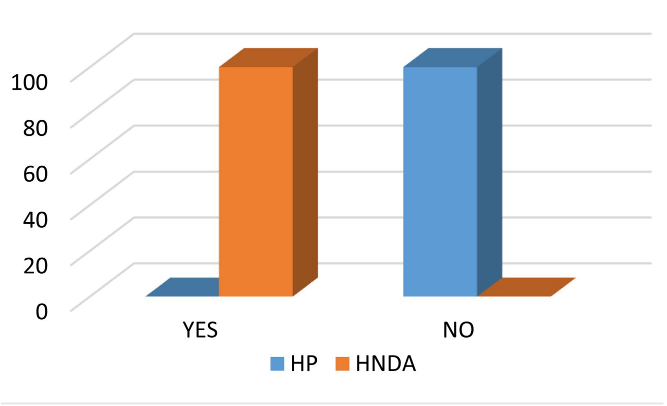

Figure 10. Vaccination coverage of DBM management staff.

3.11. Biomedical Waste Disposal

Disposal of medical waste must comply with the provisions set out in Law N˚14/PR/98 defining the general principles of environmental protection.

The results showed that 100% of DBM incineration takes place within each plant. Only HNDA had a small-scale incinerator, while HP did have an electric incinerator, which unfortunately broke down around five years ago and is no longer in operation.

These results are close to those found in the work of N'Zie et al. (2018), where 50% of health facilities in Côte d'Ivoire had at least one functional, small-scale incinerator. With no incinerator, the HP disposed of its sharps waste, highly contaminated laboratory waste (slides, pipettes, tubes and culture fields), mixed with DAOM without prior treatment, by burning it in the open air in its central storage area located some 40 m behind the medicine and ophthalmology building, without any security from where access is allowed to all those exposed to the various risks. Harouna (2012), in his research on medical waste management in Africa, made the same observation. He points out that open-air incinerators carry enormous health risks, and can be a source of lung infections and cancers. The Sarh Provincial Hospital does not bury its waste residues for months or even a year. It hires a Benz truck to remove it, and dumps it on the municipal site, sometimes in the Chari riverbed.

HP. This figure illustrates the poor management of waste from these activities, which considerably increases the risks to health and the environment. At HNDA, incineration takes place on a site equipped with a small-scale incinerator. To this end, only incineration staff have access.

Open burning and incineration of healthcare waste can, in certain circumstances, give rise to emissions of dioxins and furans, which are persistent organic pollutants (POPs) and particulate matter. Generally speaking, the disposal of DBM, whatever its form, involves potential dangers of environmental degradation. A 2017 WHO study states that, due to the possibility of heavy metal content, ash from incineration or open burning should be discharged to a special site (or ash pit). If HNDA uses the landfill system for residues and TPDs without prior treatment, this could contaminate the groundwater and cause an environmental and human health problem.

The similarity between the two hospitals in terms of waste disposal suggests that much remains to be done to reduce their impact on the environment and public health. What's more, medical and paramedical staff are unaware of the gaseous products that volatilize when antibiotic ampoules and vials are handled, which can have repercussions on the visual system of nursing staff, patients and even sick attendants.

3.12. Physico-Chemical and Bacteriological Water Parameters

Analyses are carried out at the national water laboratory of the Ministry of the Environment, Water and Fisheries in Sarh. The results of the various analyses are presented in Table 10 and Table 11.

Table 10. Water physico-chemical parameters.

Parameters	Units	Ech1 (HP)	Ech2 (HNDA)	Ech3 (Well)	WHO/Chad guidelines (2010)
pH	⌈H_3O^+⌋	**5.36**	6.91	6.70	6.5 ≤ pH ≤ 9
Temperature	˚C	30.9	30.8	30	
TDS	ppm	48.5	52.3	39.95	no mention
Conductivity	µs/cm	96.1		79.9	≤2500
Turbidity	UNT	2.32	2.05	**77.4**	≤5
TH ($CaCO_3$)	˚F	16	14	34	no mention
[HCO_3^-]	mg/l	14.64	12.2	21.96	no mention
[Cl^-]	mg/l	08	12	10	≤250
T_{Ca2+}	mg/l	5.6	04	4.8	≤200
T_{Mg2+}	mg/l	0.48	0.968	6.29	≤50
[NO_3^-]	mg/l	05	0.3	07	≤50
[SO_4^{2-}]	mg/l	-1	0	1.78	≤250
[Fe^{2+}]	mg/l	**0.49**	0.25	**1.78**	≤0.3
[NH_4^+]	mg/l	0.33	0.22	**>3.5**	≤1.5

Table 11. Water bacteriological parameters (standard deviation).

Bacteria	Volume	Ech1 (HP)	Ech2 (HNDA)	Ech3 (Well)	WHO/Chad guidelines (2010)
Total coliforms 36˚C ± 1˚C at 24 h culture medium, *chromocult agar*	100 ml	134	27	107	
Escherichia coli 36˚C ± 1˚C at 24 h, *chromocult agar* culture medium	100 ml	24	08	101	Not to be found in a 100 ml test sample
Fecal enterococci 36˚C ± 1˚C at 48 h, *glanetz* and *Bartheey* culture medium	100 ml	34	24	41	

According to Beaulieu (2021), the water we consume contains mineral and organic substances in their raw state, some of which come from rocks and sedimentary layers, and others from discharges caused by human activities or the decomposition of biomass. The results of the physico-chemical parameter analyses showed that most of the parameters analysed were within the WHO range (WHO, 2017b), with the exception of pH and iron in the first sample, as well as the third sample, which showed high levels of turbidity, iron and ammonium, making these two sources unsuitable for drinking water. For drinking water quality, the WHO recommends a pH value between 6.5 and 9; turbidity less than 5 ml; iron ions less than 0.3 ml and ammonium ions less than 1.5 ml. The concentration of ammonium ions (NH_4^+) in sample no. 3, illustrates pollution and indicates contamination from domestic discharges, as well as decomposition of vegetation. This contamination is confirmed by the work of Tababouchet (2017) who discussed the case of surface and groundwater pollution in the Sebaou watershed in Algeria.

The results of the analyses show that the three (3) samples analyzed were rich in microorganisms: the number of *total coliforms* was 134, which explains why the HP borehole is so much more contaminated than the HNDA castle and the well close to it; the number of *Escherichia coli* and *faecal enterococci* was 101 and 41 respectively, which qualifies the well as more contaminated than the castle and the borehole. **Table 11** shows that these results do not comply with WHO guidelines for drinking water. The presence of indicator germs in these different waters was highlighted, and they require prior bacteriological treatment before consumption. The presence of these microorganisms in the water is thought to be due to poor DBM management.

4. Conclusion

Hospital waste is a by-product of healthcare activities. However, it remains a real public health problem, and its management remains a preoccupation for politicians and the health establishments that manage it. Despite certain efforts, hospital waste management in the health facilities studied remains inadequate, and the hypotheses put forward are verified.

Various types of waste are produced in the two facilities; the hospital waste management circuit is not respected; in addition, physico-chemical and bacteriological analyses of drinking water in these hospital facilities have revealed poor quality in relation to WHO standards. Faulty hospital waste management is a reality in Chad's health facilities in general, and in particular at the provincial and Notre Dame des Apôtres hospitals in Sarh, where malfunctions have been noted throughout the hospital waste management circuit. This situation entails potential risks for the health and safety of health care staff, patients and the general public, as well as environmental degradation. It would be advisable for hospitals to have qualified DBM management staff and a good hospital waste management circuit to reduce environmental risks and the proliferation of infectious diseases, so as to prevent patients entering hospital from leaving with another illness.

Conflicts of Interest

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

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