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Assessment of the Impacts of Biomedical Waste Management on the Physical and Chemical Qualities of Surface Water in Benin

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ABSTRACT

This work focuses on the management of biomedical waste at the University Hospital Center for Mother and Child - Lagune of Benin wich exhibits deficiencies in compliance with regulations. The study aims to comprehensively assess all stages of solid waste management, including collection, transportation, conditioning, storage, treatment, and final disposal. Weaknesses in waste management are evident, encompassing insufficient trash cans, garbage mixing, incinerator malfunctions, and a lack of training for most hygiene and purification personnel. Furthermore, the study conducted physical and chemical analyses on the wastewater discharged from both the laundry and the wastewater treatment plant (WWTP) into the Cotonou lagoon. Field measurements were taken for physical parameters using a multiparameter measuring device. The suspended solids were determined through filtration, and nitrates and nitrites were quantified using the Nessler and Zambelli methods, respectively. BOD (Biochemical Oxygen Demand) was assessed using a BOD meter, while COD (Chemical Oxygen Demand) was determined through oxidation with potassium dichromate. The analysis results for the laundry's wastewater revealed COD levels of approximately 146 mg/L, BOD5 at 62 mg/L, and suspended solids at 63.74 mg/L. These values, exceeding Benin's standards, raise concerns about the potential impact of discharging these waters into the Cotonou lagoon. It is imperative that these wastewater streams be directed to a treatment station before being released into the lagoon.

1. Introduction

Healthcare activities produce a considerable volume of hospital waste, with some presenting infectious risks, while others without specific risks can be considered akin to household waste [1]. Due to their unique nature, biomedical waste (BMW) necessitates management in compliance with prevailing legislation and regulations across all countries. This ensures the safeguarding of the health of individuals involved in waste management and those associated with the surrounding environment. Unfortunately, inadequate waste management practices are observed in certain hospital facilities. In Benin, it is imperative to implement additional precautions at the University Hospital Center for Mother and Child - Lagune (CHU-MEL) to mitigate the impact of waste generated within the facility on the environment. This study seeks to provide an overview of the management of biomedical waste at CHU-MEL and assess its impact on both the hospital staff and the surrounding environment.

2.1. Presentation of the Study Area

The CHU-MEL is situated between 6°21’39’’ and 6°21’44’’ North latitude and 2°26’14’’ and 2°26’19’’ East longitude in Cotonou.

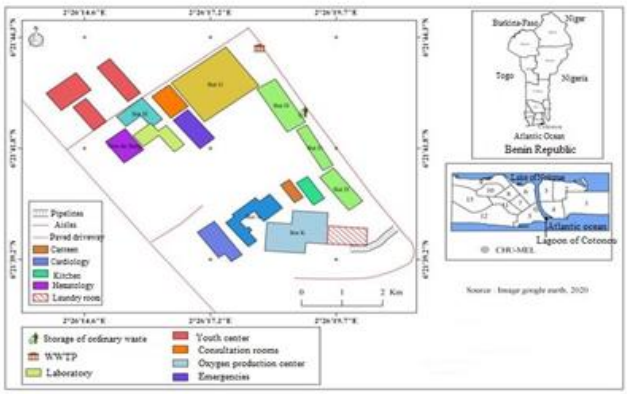

Figure1. Localization of CHU-MEL and its different departments

2.2. Data Collection

Qualitative and quantitative demographic and climatological data related to the management of solid and liquid waste within CHU-MEL, as well as information regarding nosocomial diseases, were gathered from archives and through real-world investigations. This involved observations and interviews with stakeholders and users of the facility.

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2.2.1 Sampling

2.2.1.1 CHU-MEL Staff and Users

Sampling was conducted using the reasoned choice method, selecting individuals involved in waste production, biomedical waste management, and local residents. This included health service managers, nursing staff, pharmacy staff, laboratory staff, hygiene workers, maintenance workers, local fishermen, and hospital administrative managers. A total of 97 workers were interviewed out of 654, representing all categories, and 50 interviews included fishermen.

2.2.1.2 Wastewater Sampling

Wastewater samples were collected during the dry season in August and September in 1.5L plastic green bottles, previously washed and rinsed. These samples were taken from discharge points of effluents by the waste water treatment and purification station (WWTP) and the laundry room (LR). Before sampling, effluents were homogenized in the pit where they passed before being discharged into the Cotonou lagoon. Samples were transported to the laboratory in coolers with ice accumulators at approximately 4°C to maintain their integrity. In situ measurements included temperature, electrical conductivity, and pH using a multiparameter salinity conductivity meter type ProLine LF 197/LF 197.S. Suspended solids levels were determined through filtration on a GFC filter and drying at 105°C (AFNOR, T90.105). Nitrate content was obtained by the Nessler method, nitrite by the Zambelli method. Biochemical oxygen demand (BOD) was determined by incubating samples in the dark at 20 ºC in a BOD meter type a6 posti BOD system 10 containing bottles equipped with a BOD sensor. Chemical Oxygen Demand (COD) was determined by excess oxidation with hot potassium dichromate in an acidic medium (AFNOR NT 90.101 method). Ammoniacal nitrogen rate was determined by distillation followed by ammonium determination by acidimetry. NTK determination was done by distillation in a K – 314 BÛCHI distillation unit, preceded by mineralization in an acidic environment of the organic nitrogen into ammoniacal nitrogen [2].

3. Results and Discussion

3.1. Frequent Illnesses Encountered at CHU-MEL

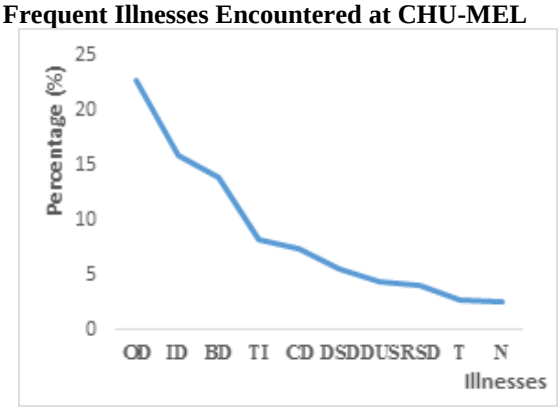

Figure 2. Percentage of illnesses encountered at CHU-MEL

Legend: Legend: OD: Obstetric Diseases; ID: Infectious Diseases; BD : Blood Diseaas TI: Traumatic Injuries; CD ; Circulatory System Diseases : CD ; DSD: Digestive System Diseases; DUS: Diseases of the Urogenital System; RSD: Diseases of the Respiratory System; T: Tumors; N: Neonatology Diseases.

Figure 2 illustrates that the diseases predominantly diagnosed and treated in this facility are primarily of neonatology and obstetric origin. This aligns with the center's true purpose.

3.2. Nature of Solid Waste from CHU-MEL

Table 1 summarizes the solid waste encountered at CHU-MEL.

Table 1. Composition of Biomedical Waste at CHU-MEL

Waste Category	Composition
Infectious non-anatomical waste (INAW)	Cotton, compress, plaster, finger gloves, leftover casts, bandages.
Anatomical human waste (AHW)	- Physiological fluids (blood, urine, sputum, stools, vomits, pus, amniotic liquids…)
	- Human body parts: organ debris, placentas, amputated limbs, etc.
Pointed or sharp objects (PSO)	Needles, syringes, forceps, blades, coverslips…
Non-biodegradable waste (NBDW)	Empty bottles of serum, injectable and drinkable ampoules…
General waste (GW)	Used office equipment, medical and IT equipment, waste comparable to household waste, etc.
Pharmaceutical waste (PW)	Expired products (medications, vaccines, etc.)

The proportions of these waste are shown in figure 3

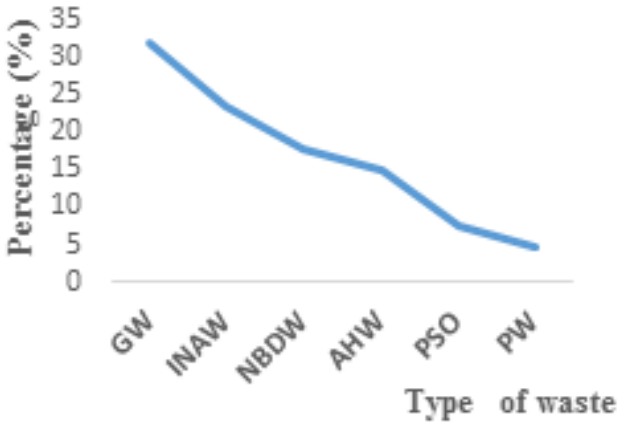

Figure 3. Proportions of different categories of waste

The analysis presented in Figure 3 reveals that general waste, comparable to household waste, constitutes the largest quantity of waste produced at CHU-MEL. However, a significant portion of the waste is biomedical, including infectious non-anatomical waste, human anatomical waste, and sharp objects. The cumulative total percentage of these biomedical waste categories is equal to 45.42%.

3.3. Solid Waste Management

Solid waste at CHU-MEL undergoes classic universally recommended steps, including sorting, collection, transport, storage, treatment, and final elimination (incineration or landfill).

3.3.1. Deficiencies recorded at each stage

3.3.1.1 Sorting

Despite recommendations, solid waste sorting suffers from the lack of qualification of various actors, leading to mixing in various bins. Sharp objects are stored in "safety boxes," and certain anatomical waste is separately collected.

3.3.1.2 Conditioning of Solid Waste

Solid waste is conditioned for a maximum of 24 hours in insufficient or degraded bins in various services and care units by caregivers and maintenance workers.

3.3.1.3 Collection

Daily collection and transport of waste between services use leaky, uncovered, and unlabeled carts, violating requirements. General waste is then removed using such carts to a public dump.

3.3.1.4 Incineration and burial

General waste is sometimes found mixed with biomedical waste, and defective incinerators lead to ashes being poorly buried, escaping and polluting the environment.

The improper disposal of infectious non-anatomical waste and anatomical human waste into surface water can introduce harmful pathogens and biological contaminants, posing risks to both aquatic life and public health. Disposing of expired medications, vaccines, and other pharmaceutical waste can lead to the release of chemicals into surface water. This can alter the chemical composition of the water and potentially introduce harmful substances into the environment. Liewise disposing of expired medications, vaccines, and other pharmaceutical waste can lead to the release of chemicals into surface water. This can alter the chemical composition of the water and potentially introduce harmful substances into the environment.

4. Liquid waste management

Liquid waste includes discharge from the laundry room and effluents from various services and care units, conveyed to a sewage tank before discharge into the Cotonou lagoon.

4.1 Physical and chemical characteristics of liquid effluents

The temperature remained constant at 28°C on average during the study period.

4.1.1 pH Variations

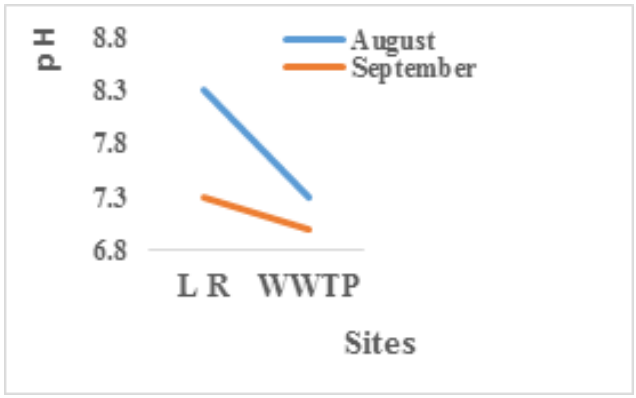

Figure 4. Variations of pH depending on sites and seasons

Values indicated on figure 4 respect Beninese and French standards, maintaining the neutrality of the lagoon water. They are also comparable to those obtained on raw wastewater from the hemodialysis center of Al Ghassani Hospital in Fez, Morocco [3].

4.1.2. Variations of Electrical Conductivity (EC)

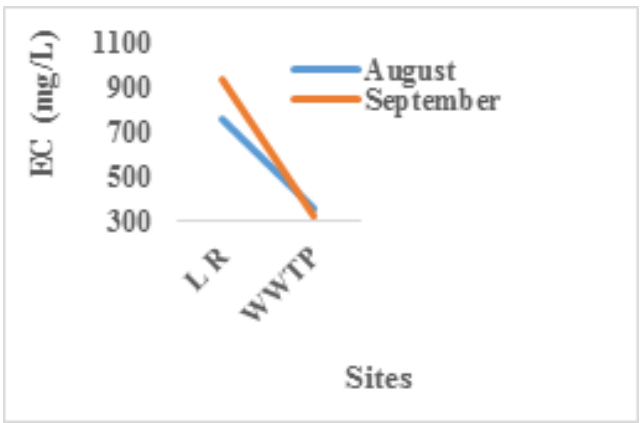

Figure 5. Variations of electrical conductivity depending on sites and seasons

Values of figure 5 are higher than those recorded at the Yaounde University Hospital [4] at the outlet of the treatment plant (538± 83.86) µS/cm, indicating strong mineralization that may disrupt aquatic life at the point of discharge.

4.1.3 Suspended Solids (MES)

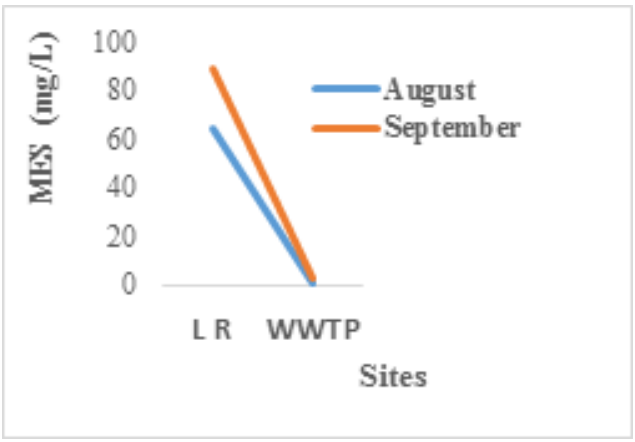

Figure 6. Variations of suspend solids levels depending on sites and seasons

Suspended solids levels from the laundry room exceed Senegalese standards (50 mg/L) [5] for waste water. They are , however, lower than the average of 199.8 mg/L obtained for raw wastewater at the CHR Mohamed V in Safi in Morocco and the usual values for Moroccan urban water (250.5 mg/L) [6]. They are also lower than the French standard (500 mg/L) and the maximum of 550 mg/L recorded at the Hyeres Hospital Center in Var in France in 1999 [7], emphasizing the need to reduce this rate to avoid environmental impacts. The release of suspended solids from the laundry room, can adversely affect water quality. High levels of suspended solids may lead to reduced light penetration, hindering photosynthesis, and negatively impacting aquatic organisms.

4.1.4. Biochemical Oxygen Demand for 5 Days (BOD5)

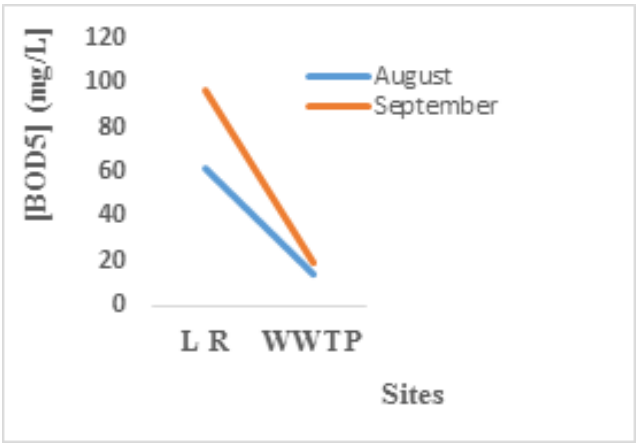

Figure 7. Variations in BOD5 depending on sites and seasons

Values of figure 7 are below the French standard (800 mg/L) and those recorded at the Limoges CHUR which are between 177 mg/L and 535 mg/L [8] and especially those (≥ 700 mg/L) still recorded at Hyeres Hospital (VAR)in France [7]. The values obtained at the WWTP outlet are lower than the average of 60 mg/L obtained at the outlet of the C.H.U's WWTP in Cameroon and lower than the standard of 50 mg/L in this country. They are also lower than the Beninese standard (30 mg/L) [9]. But those, however, from the laundry room exceed the Beninese standard, potentially impacting water quality at the point of discharge.

4.1.5. Chemical Oxygen Demand

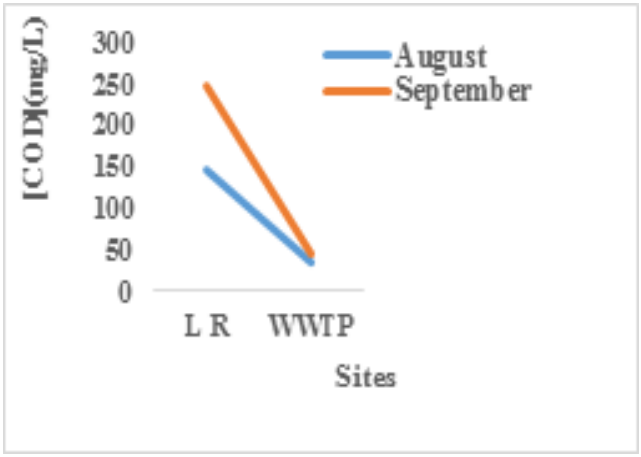

Figure 8. Variations in COD depending on sites and seasons

COD values obtained at the outlet of the WWTP are all below the Beninese standard (125 mg/L) [9] but those from the laundry room, are higher than the Beninese standard, indicating harm to the Cotonou lagoon's waters. All the values recorded are below the French standard (2000 mg/L) [8] and particularly the high concentrations (≥ 1,900 mg/L) still noted in France in 1999 [7]. Except for that recorded at the laundry room in August, the values recorded are also lower than those obtained at the Yaounde University Hospital and the standard (200 mg/L) [4] for wastewater discharge in this country. The discharge of liquid waste, especially from the laundry room, can contribute to high levels of BOD and COD in surface water. Elevated BOD and COD can deplete oxygen levels, negatively impacting aquatic ecosystems and leading to the formation of oxygen-deprived zones.

4.1.6. Biodegradability of CHU-MEL Wastewater

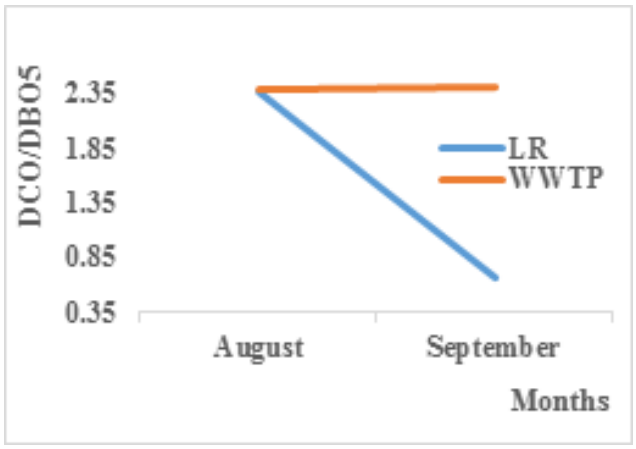

Figure 9. COD/BOD of wastewater depending on sites and seasons

All values indicate easily biodegradable wastewater (COD/BOD5<3), posing a potential threat to aquatic life and human safety. The easily biodegradable nature of wastewater discharged from CHU-MEL, as indicated by low COD/BOD ratios, may lead to the assimilation of organic matter by fish species. This could result in the bioaccumulation of contaminants and pose risks to both aquatic life and human consumers.

4.1.7. Phosphorus Levels in the Laundry Room and WWTP

Figure 10. Total phosphorus contents during the month of September

The values recorded during September (figure 9) are much lower than those obtained by Mbog (2013) [4] in Cameroon. Low levels indicate minimal involvement of phosphorus derivatives in degrading water's physical and chemical qualities in Cottoned lagoon.

4.2. Nitrogen Pollution

4.2.1. Nitrite ion contents

Nitrite levels are well below 10.2 g/L, posing no danger to receiving waters.

4.2.2. Nitrate and ammonium ion contents

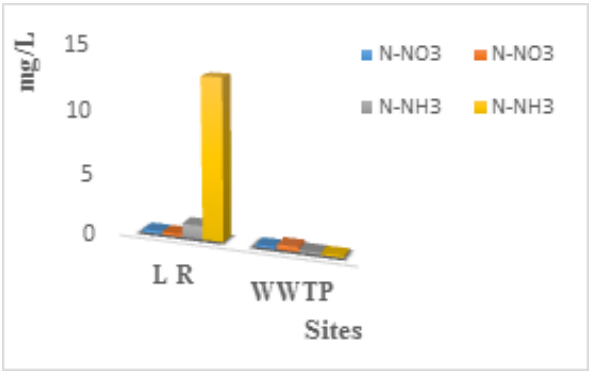

Figure 11. Nitrate and ammonium contents depending on sites and months

Nitrate and ammonium contents (Figure 10) are lower than those obtained in Cameroon by Mbog [4]; those in ammonium in particular are significantly lower than that obtained at the Limoges University Hospital in France [8]], indicating a lower risk to receiving waters.

4.3. NTK Contents

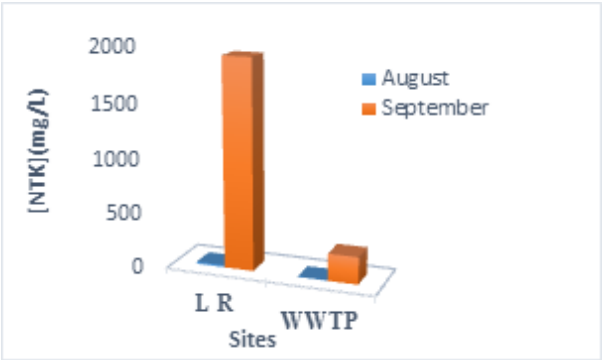

Figure 11. NTK contents according to sites and months

NTK values (figure 11) obtained in August meet those recorded at the Yaounde University Hospital in Cameroon [4]. In August and september they are lower than those recorded at the Limoges University Hospital [8]. The values exceed Beninese standards which are 200 mg/L for discharges of less than 50 mg/L of pollutants and 30 mg/L otherwise posing a danger to the receiving environment [9]. The fluctuations observed in the recorded values are comparable but to a lesser extent to those observed by Chedevergne in wastewater discharged by the Dupuytren Hospital [10] in France. The direct discharge of untreated wastewater into the lagoon, especially during rainy weather, poses health risks to the staff and the community. Mixing with runoff water can exacerbate the contamination of surface water.

Conclusion

The CHU-MEL wastewater management poses significant challenges, indicating issues with the wastewater purification and treatment station and the direct discharge of wastewater into the lagoon. The inadequate management of biomedical waste at CHU-MEL can have far-reaching consequences on the physical and chemical qualities of surface water, affecting aquatic ecosystems, public health, and the overall environmental integrity of the surrounding area. Urgent measures are required in the short term, with long-term solutions focusing on technical improvements to mitigate these impacts and ensure sustainable waste management practices. Addressing these challenges is crucial for achieving environmental health goals, especially in urban areas like Cotonou.

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