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Evaluation of the Efficiency of Hospital Wastewater Treatment Systems and Stations in the Atlantic and Littoral Departments of Benin

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Abstract Healthcare institutions are responsible for the pollution of ecosystems through their activities. The waste water produced by the various departments of these facilities is piped to treatment plants where it must be treated to meet standards for discharge into the environment. In order to assess the efficiency of the wastewater treatment plants and treatment systems of large hospitals in the departments of Atlantic (the most populous department in Benin) and Littoral (the economic capital) in the south of Benin, samples were taken upstream and downstream of the treatment plants and systems installed in these centres. Physico-chemical parameters such as temperature, pH, total suspended solids and TDS were measured "in situ" using an AQUAREAD multimeter. The other pollution parameters (COD, BOD5, TN, total phosphorus) were determined in the laboratory according to French standards. The results obtained show that the treatment plants of the University Hospital of Mother and Child (CHU-MEL) and the Allada Zone Hospital (CHZ Allada) are effective, with high reduction rates of 43%. 100% for suspended solids, 60 to 100% for TSS, 100% for total phosphorus and COD and 97% for BOD5. The laundry treatment systems of the CHU-MEL and the St Luc Hospital in Cotonou are less effective with reduction rates of 2 to 13% for TSS, 7 to 35% for BOD5, 5% for COD, 0 to 16% for TSS and 5 to 9% for total phosphorus. At the microbiological and parasitological levels, almost all samples taken and analysed after treatment are free of microorganisms and parasites. In view of the danger that this type of waste poses to the environment, and in view of the reduction rates and the values of the physico-chemical parameters of the effluents obtained in this study, it is urgent to promote the installation of treatment stations for this type of waste in the centres that do not yet have them, while ensuring the maintenance and proper functioning of the existing ones.

Keywords: *Pollution, Hospital effluent, Microbiological analysis, Physico-chemical analysis, Benin*

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1. Introduction

Healthcare facilities, due to the specific nature of their activities, produce effluents that are likely to cause environmental degradation with serious consequences for the health of staff and users. These hospital effluents contain various toxic or persistent substances such as pharmaceuticals, radionuclides, solvents and residues of medical disinfectants in a wide range of concentrations [1,2,3]. The management of hospital wastewater is therefore becoming a real problem in developing countries due to the lack of treatment facilities and, more importantly, management practices [4]. In many of these countries, hospital wastewater is discharged untreated to the receiving environment (rivers, lowlands) through public sewers [5,6,7,8]. Through the phenomenon of leaching, these pollutants are responsible for eutrophication. Despite the risks associated with these types of hospital effluents, in most countries there are no legal requirements for their management and, in particular,

for their treatment methods before discharge. In many of these countries, particularly in Africa, the management of hospital wastewater could be a risk with serious consequences. High levels of these pollutants in untreated discharges can lead to, among other things, various waterborne diseases in humans and eutrophication of waterways. These discharges are also not without consequences for the species that inhabit these natural physical environments. The aim of this study was to carry out a physico-chemical and microbiological characterisation of the effluents of the hospital centres of the Atlantic and Littoral Departments, before and after treatment, in order to alert the public to the potential consequences of the discharges on living organisms and the environment.

2. Materials and Methods

Study setting

This study is based on university hospital centers (CHU), zone hospital center (CHZ) of the Atlantic and Littoral Departments, as well as private centers with a similar technical platform. The choice of university hospitals was motivated by the availability of a station and/or a treatment system for their wastewater. There are 12 CHZ level centers in the Atlantique and Littoral departments, with the exception of the National University Hospital Center Hubert Koutoukou MAGA, which was excluded from our study because of its status as a reference centre, having been the subject of several previous studies. The other centers with a unit or treatment system were included in this study, namely University Hospital of Mother and Child (CHU-MEL), which has both a ward and a treatment system, the Allada Zone Hospital, which has a treatment station, and the Center with Humanitarian vocation St Luc, which has an effluent treatment system (Table 1).

Table 1. Sampling points and geographical coordinates

N°	Denomination of the sites	Codes	Coordinates
1	Wastewater treatment plant of the University Hospital Center for Mother and Child of Cotonou	CHU-MEL	6,2142N et 2,2616E
2	Laundry System of the University Hospital Center for Mother and Child of Cotonou	Buand CHU-MEL	6,3608N et 2,2618E
3	Wastewater treatment plant of the Allada Zone Hospital	CHZ Allada	6,7044N et 2,1354E
4	System of the Hospital for Humanitarian Vocation St Luc of Cotonou	St Luc	6,3844N et 2,4030E

Sampling method

Samples for physicochemical analyses were collected in 1.5 litre plastic bottles that had been rinsed three times with the effluent to be sampled. For microbiological analyses, samples were collected in sterile 25 mL tubes according to the method described by Todedji *et al*. [9]. These samples were collected at the inlet (pre-treatment) and outlet (post-treatment) of the stations and/or systems to assess the efficiency of the treatment devices. After collection, the samples were labelled and then transported in coolers equipped with thermostats to prevent their transformation (biological, physical or even chemical).

Analytical methods

Certain physicochemical parameters such as temperature (T), conductivity (σ), total dissolved solids (TDS), pH and turbidity (Turb) were evaluated "in situ" using an AQUAREAD multimeter.

Table 2. Standard methods used to determine laboratory parameters

NO_2^-	The method is based on the reaction of NO_2 ions with 4-aminobenzene sulfonamide at pH = 1.9 in the presence of de H_3PO_4 to form a diazo salt which complexes with N- (Naphtyl-1) diamino dihydrochloride 1,2-ethane to give a pink color whose intensity is proportional to the NO_2 content and measurable at 540 nm	NF EN 26777
Total phosphorus	The method relies on the reaction of H_3PO_4 ions with an acid solution containing molybdate and antimony ions to form an antimonyl phosphomolybdate complex which is reduced by ascorbic acid in bright-colored molybdenum blue measurable at 700 nm.	NF EN ISO 6878 (T90-023)
BOD_5	NF T90-101 BOD_5 Oxidation of the biodegradable organic matter contained in a water sample by natural microorganisms in the dark in amber bottles saturated with O_2 placed in a thermostatic incubator at 20°C ± 2°C for 5 days	NF EN 1899-2
COD	Acid Oxidation of Organic Matter by Excess $K_2Cr_2O_7$ in the Presence of $AgSO_4$ as Catalyst and $HgSO_4$ to Complexe Cl- and Determination of Excess Oxidant with Mohr Salt Solution ($NH_4Fe(SO_4)_2.6H_2O$)	NF T90-101

The Total Nitrogen (TN) and nitrate contents were evaluated according to the methods of Rodier [10,11].

Microbiological analyses were carried out according to the recommendations of Rodier [10,11] for Staphylococcus, coliforms, *Escherichia coli* and Enterococcus. The various culture media used were prepared and tested in accordance with the standards in force.

The various data collected after the laboratory analyses, as well as those measured "*in situ*", were processed using Microsoft Office Excel software to construct the various graphs.

3. Results

- Influence of the treatment on the physico-chemical quality of the effluents

Table 3 shows the values of the physico-chemical parameters measured "in situ" on the effluents immediately after sampling.

Analysis of this table shows that the temperature values vary between 28.01 and 29.80°C at the inlet and 28 and 29.50°C at the outlet of the treatment stations and systems. These different inlet and outlet values are all lower than the Beninese standard: < 30°C [12]. The temperature remains almost constant throughout the treatment process. The pH varies from 6.73 to 7.13 at the inlet and from 6.55 to 7.17 at the outlet. These values also correspond to the standard allowed in Benin for liquid effluents before discharge ($6 \leq pH \leq 9$). However, there is a slight increase in the pH during treatment, which could be explained by the infrastructure put in place, which favours the evolution of the pH towards a neutral value. Apart from the turbidity values of the Allada CHZ and the value at the CHU-MEL

outfall, all the other values are higher than the Beninese standard (< 5 NTU) and the WHO standard (between 7 and 9.5 NTU). The conductivity values are all lower than the Beninese standard of 2000, except for that of the outlet, which is not only slightly higher than the standard, but also higher than the inlet value. The dissolved oxygen values are all well below the Beninese standard, which is greater than 5.

Influence of treatment on the main pollution indicator parameters.

Table 3. Values of physico-chemical parameters of effluents measured "in situ

Centers	Samples	Temperature (°C)	pH	EC	TDS	Turbidity	O_2
St Luc	Entrance System	29.80	6.79	1243	807	94	1.64
	Exit System	29.50	6.98	1218	796	63	1.70
CHU-Mel	Entrance System Buanderie	29.10	7.10	2000	1112	177	1.13
	Exit System Buanderie	28.50	6.70	2050	1030	111	1.23
	Entrance Station	28.40	6.73	749	488	126	0.85
	Exit Station	28.50	7.17	515	333	02	2.16
CHZ Allada	Entrance Station	28.01	7.13	130	82	0.10	0.31
	Exit Station	28.00	6.55	82	55	0.02	1.03

- Biochemical oxygen demand (BOD_5)

Figure 1 shows the BOD_5 values of wastewater entering and leaving hospital treatment plants and systems.

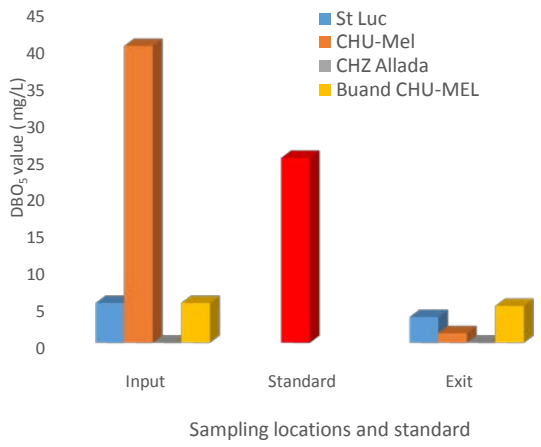


Figure 1. BOD_5 values before and after wastewater treatment

Analysis of this graph shows that the CHU-MEL station achieved a reduction in Biochemical Oxygen Demand of 96.75%, while the CHU-MEL and St Luc treatment plants achieved reductions of 7.4% and 35.18% respectively for the same parameter. The treatment plants therefore show a better performance in terms of reducing the BOD_5 of the effluent. However, it should be noted that the two treatment methods (station and system) produce effluents that comply with the standard for this parameter (<25 mg/L).

- Chemical oxygen demand (COD)

The graph in Figure 2 shows the COD values of the effluent before and after treatment.

The chemical oxygen demand was reduced by 100% at the CHU-MEL and CHZ stations in Allada. On the other hand, the treatment systems of CHU-MEL (Buand CHU-MEL) and the hospital of St Luc showed a reduction of COD of 5.08% and 5.12% respectively. As in the case of BOD_5, the treatment plants showed better performance in terms of COD reduction and all samples showed rejection rates in line with the standard.

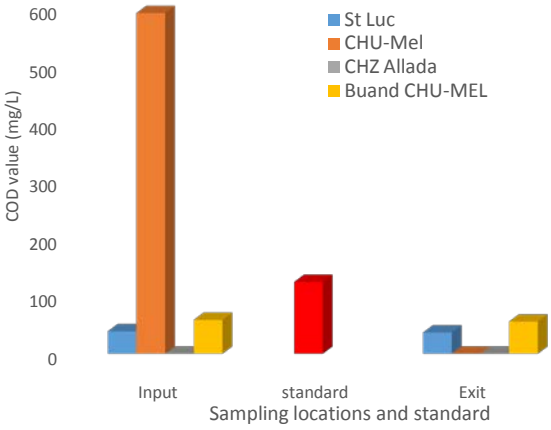


Figure 2. Effect of treatment on COD of samples

- Total Nitrogen (TN)

Total nitrogen (TN) is the sum of ammoniacal nitrogen and organic nitrogen. The values recorded on the samples taken before and after treatment at the various hospitals are shown in the graph in Figure 3.

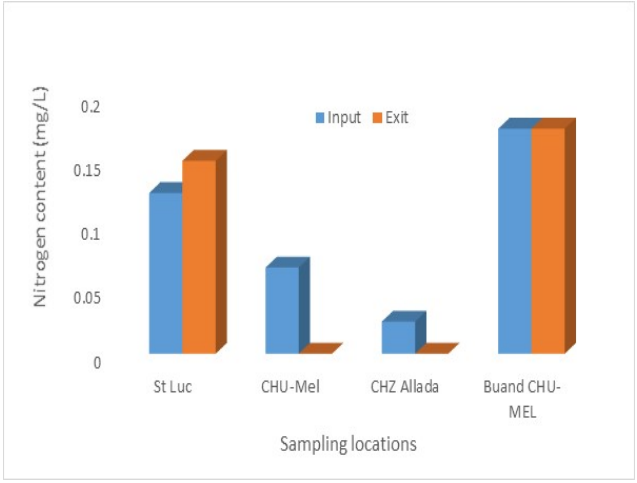


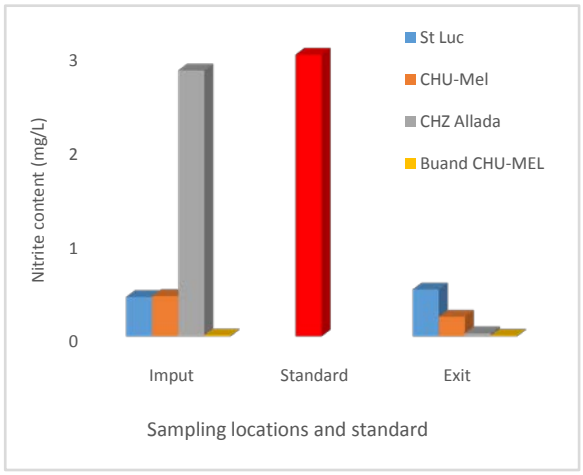
Figure 3. Effect of treatment on total nitrogen in waste water

Analysis of this graph shows that the two centres equipped with treatment plants (CHU-MEL and CHZ of

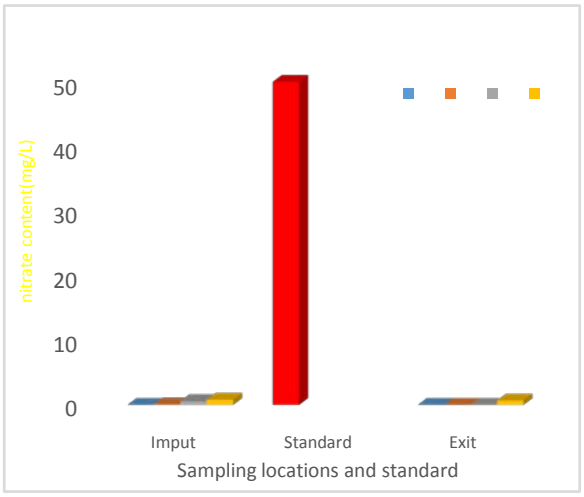
Allada) each showed a 100% reduction in total nitrogen. On the other hand, no reduction in total nitrogen was observed at the treatment plants. Despite a slight increase in the values at the outlet of the St. Luc treatment plant, the loads before and after treatment in both the stations and the treatment plants are all below the Beninese standard, which recommends values between 15 and 30 mg/L.

- Nitrite and nitrate content

The nitrites and nitrates present in water are absorbed by plants in mineral form. However, the presence of these ions in the environment is harmful to human health, not to mention the phenomenon of eutrophication. Figures 4a and 4b show the values of these parameters at the inlet and outlet of treatment plants and systems.



a- Nitrite content of effluent and standard



b- Nitrate content of effluent and standard

Figure 4. Nitrite and nitrate content of effluent before and after treatment compared to standard

The CHU-MEL and CHZ stations in Allada achieved reductions of 51.16% and 94.3% respectively in the nitrite content of the effluent. All effluents from these stations and treatment systems comply with the Beninese standard, which requires a level of less than 3 mg/L. With regard to nitrate, the CHU-MEL and CHZ stations in Allada each achieved a 100% reduction. These nitrate levels in the samples before and after treatment are well below the Beninese standard of 50 mg/L.

- Total phosphorus and suspended solids

Figure 5 shows the phosphorus levels before and after treatment in the stations and treatment systems.

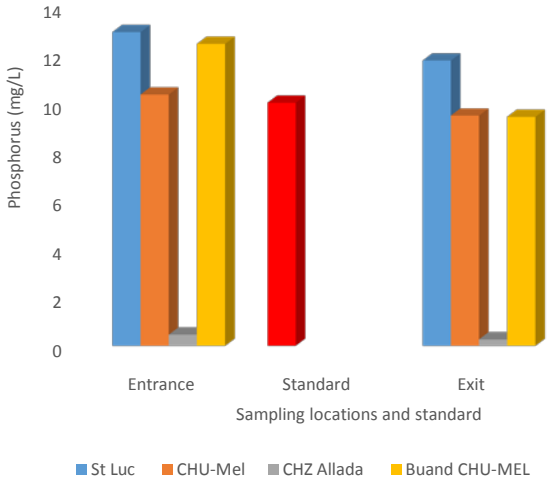


Figure 5. Phosphorus levels before and after treatment

The CHU-MEL and CHZ Allada showed reductions of 8.41% and 42.1% respectively, compared to 9.14 and 24.21% for the treatment systems of St Luc and Buanderie CHU-MEL. The values measured for total phosphorus after treatment of the hospital effluents are almost all slightly higher than the Benin standard, with the exception of the CHZ Allada. In view of the reduction rates obtained, additional treatment of these effluents should be considered in order to bring the phosphorus rate into line with the discharge standards. The suspended solids values at the inlet and outlet were all higher than normal, with the exception of the hospital in the Allada zone (10 mg/l).

-Microbiological quality of treated effluent

The results of the microbiological analyses are given in Table 4 and Table 5.

Table 4. Results of microbiological analyses of effluents from treatment plants and systems

Samples	*Staphylo-coccus spp* (CFU/mL)	Faecal coliforms (CFU/mL)	*Escherichia coli* (CFU/mL)	*Enterococcus faecalis* (CFU/mL)	*Salmonella typhi murium* (CFU/mL)	*Pseudomonas aeruginosa* (CFU/mL)
St Luc	$2.2\ 10^4$	< 1	< 1	$2\ 10^1$	< 1	>1
Buanderie CHU-MEL	2.10^4	< 1	< 1	< 1	< 1	>1
Station CHU-MEL	10^3	< 1	< 1	< 1	< 1	>1
CHZ Allada	10^2	< 1	< 1	< 1	< 1	>1

Table 5. Results of parasitological analyzes of effluents at the inlet and then at the outlet of treatment plants and systems

Samples	Protozoa				Helminths
	Flagellates	Amoebas	cysts		
	Giardia lamblia	*Entamoeba histolytica*	*Entamoeba histolytica*	*Entamoeba coli*	
St Luc	-	+	-	-	+[a]
	-	+	-	-	-
Buanderie CHU-MEL	-	-	++	-	-
	-	-	+	-	-
Station CHU-MEL	+	+	++	++	-
	-	-	-	+	-
CHZ Allada	-	-	-	-	-
	-	-	-	-	-

[(a)]=pinworm eggs ; (-) = absence ; (+) = low presence ; (++) = strong presence

One of the hospital effluents shows the presence of Salmonella, unlike *Pseudomonas aeruginosa*, which is present in all samples. As for *Escherichia coli*, it is not present in any of the effluents.

Reading this table shows that all the samples taken at the entrance to the treatment stations and systems contain parasitic elements such as protozoa in vegetative or cystic form, helminth eggs, with the exception of the samples from the CHZ of Allada. The different stations and treatment systems of the centres have carried out a real filtering of the parasitological elements of the effluents.

4. Discussion

The activities of hospitals generate wastewater, the treatment of which requires the installation of well-defined equipment and management plans to reduce the level of pollutants present before discharge into the natural environment. In order to assess this treatment, effluent samples were taken and analysed at the inlet and outlet of a number of treatment plants and systems in hospitals located in the Atlantic and Littoral departments of southern Benin. These different treatment plants and systems found in the field showed, for the most part, a reduction in chemical parameters such as BOD_5, COD, total nitrogen, nitrite and nitrate. However, these systems react differently to phosphorus levels. The reduction rates for this parameter obtained in these stations and treatment systems are relatively low, with the exception of the CHZ station in Allada, which shows a reduction of almost 50%. These values are close to those found by Yovo [13], Touzani *et al*. [5] and Todedji *et al*. [14] The acceptable rate (50%) obtained at the CHZ station in Allada could be explained by the new character of this station compared to that of CHU-MEL, which is in an older state and suffers from a lack of maintenance. From a microbiological point of view, all the effluents collected at the level of the different hospital centres after treatment are free from microorganisms such as faecal coliforms, Escherichia coli and Salmonella typhi murium, unlike Staphylococcus spp and Enterococcus faecalis, which are found at average levels. These results are much lower than those of Ameziane and Benaabidate., [14]; El Mountassir *et al*., [16] and the WHO standard [17], which are 7.44.106, 46.104 and 1000 CFU/100 mL respectively. Linking the concentration of faecal coliforms to the degree of contamination with germs, in line with the work of Emmanuel *et al*. [18], we can conclude that the effluents of the Atlantic and Littoral hospital centres either originally contain fewer microorganisms (less contaminated) or more antibiotics or detergents, which would be the basis for the reduction in the rate of microorganisms. The decontamination carried out by the staff of the hospitals concerned would therefore explain this observation. The use of cleaning products such as disinfectants and antiseptics, of which bleach is the best known and most widely used, in high concentrations in hospitals would be at the origin of the reduction in the concentration of bacterial flora. [19]. The presence of non-metabolised antibiotic residues in hospital wastewater would contribute significantly to the selection of multiresistant bacteria in wastewater [20]. Microbiological examination of these effluents also shows that they contain staphylococci to varying degrees. Other studies have also confirmed the presence of bacteria in hospital effluents, such as Staphylococcus [21] and Enterococcus [16,22]. Some hospital effluents from the Atlantic and Littoral regions contain protozoa and helminths in addition to microorganisms. It is therefore correct to state, as Makoutodé *et al*. do, that hospital effluents, like domestic water, are nests of several pathogenic species (coliforms, viruses, bacteria, helminths, etc.) [23]. This observation confirms that of Rodier, who stated in 1996 that hospital wastewater, like domestic water, can contain microorganisms and parasites. The presence of these protozoa may be linked to the sanitation system (sewage collection) of certain centres connected to septic tank networks. Often found in surface water, these sometimes highly pathogenic elements survive for long periods in the environment and are highly resistant to chlorine disinfection. The World Health Organization [24] estimates the global incidence of giardiasis at 200 millions cases per year. Comparing hospital wastewater with domestic wastewater, the WHO states that a large proportion of healthcare wastewater is of similar quality to domestic wastewater and poses the same risks. Like domestic wastewater, healthcare wastewater should be considered potentially infectious and deserves similar precautions in its management. However, a large proportion of healthcare wastewater presents a higher risk than domestic wastewater and requires special management. Depending on the level of service and the functions of the healthcare facility,

wastewater may contain chemicals, pharmaceuticals or infectious biological agents, and even radioisotopes [25]. To protect the environment, it would be necessary, if not imperative, to find a treatment method capable of simultaneously removing chemical contaminants, protozoa and microorganisms from these effluents.

5. Conclusion

The aim of this study was to evaluate the effectiveness of wastewater treatment stations and systems in hospitals located in the Atlantic and Littoral regions of Benin. The results obtained show that the station at the University Hospital of Mother and Child (CHU-MEL) has one of the best reduction rates for the main pollution parameters (COD, BOD5, TN), despite the high load of treated effluents and the lifetime of this station. The effluents produced at the level of the hospital in the Allada area are less polluted and this low pollution, combined with the new nature of the station, results in effluents that meet the standards for environmental discharges. From a microbiological point of view, the treated effluents all comply with the WHO discharge standards, with the exception of the effluents from St Luc and the CHU-MEL buanderie, which contain staphylococci above the standard. The parasitological tests carried out show the presence of rare pinworm eggs and some protozoa. There was also a significant reduction in parasites (protozoa and helminths) in most stations and treatment systems. Taking all parameters together, only 25% of the stations and treatment systems in the centres surveyed have values that meet the standards for discharging effluent into the environment. However, the treatment plants proved to be more efficient than the treatment systems. In view of the values obtained at the level of the treatment systems, it is necessary to review their operation or to add a complementary treatment method to them in order to bring their discharges into line with the standards in force, in order to better protect the population, the environment and aquatic biodiversity.

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