



Heavy Metal Content (Hg, Pb, Cd and Fe) of CHU-MEL Effluents Discharged in the Cotonou Lagoon (Benin)

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Abstract: This study is conducted to characterize the heavy metal contamination of CHU-MEL effluents discharged into the Cotonou lagoon in order to assess the potential risk of these discharges for this ecosystem. To achieve this objective, the effluents collected at the end of the pipes acting as weirs in the lagoon were analyzed. The results from physico-chemical and heavy metals analyzes have made it possible to assess the quality of the effluents. The values of pH, temperature, conductivity, TDS and dissolved oxygen measured in situ are, on average, 7.95; 29.60°C; 639.60 µS/cm; 457.48 mg/l and 0.22 mg/L. The determination of heavy metals in the effluents showed low levels of contamination. The average levels of lead, cadmium, mercury and total iron are 0.1727 mg/L, 0.0261 mg/L, 0.0010 mg/L and 0.25 mg/L, respectively. This study shows that most of the parameters studied in the CHU-MEL effluent are in compliance with the standards. These effluents therefore pose a low risk for the aquatic organisms of the receiving environment, this added to the dilution effect of the effluents in the waters of the lagoon. However, the continual discharge of these effluents into the lagoon with their share of heavy metals.

Keywords: Aquatic Environment, Heavy Metal, Hospital Effluents, Pollution

1. Introduction

Pollution of aquatic environments in developing countries has been an international concern for decades. In fact, water pollution in these countries has already taken considerable proportions for more than a half century [1]. In addition, environmental protection requires knowledge of the destiny of these pollutants in the environment and their effects on aquatic ecosystems [2]. Among the sources of pollution of

the aquatic environment, the discharge of hospital effluents is particularly important. The discharge generated by hospital activities may be dangerous for humans and their environment given the nature and importance of the specific substances they contain (drug residues, chemical reagents, antiseptics, detergents, X-rays developers and fixer...). Their evacuation, as well as the traditional urban discharges, to the municipal sanitation network without prior treatment [3] also contribute to such situation. Among other pollutants, hospital effluents contain and trap heavy metals in aquatic

environments [4-6]. These heavy metals are source of serious ecological problems. This is linked, on the one hand, to their ability to be found in food chains inner the biosphere and on other hand, to their toxicity. Also, their ability to bio-accumulate and bio-amplify in several aquatic species has devastating effects on the aquatic environment [7-8].

In Benin, according to Decree N° 2006-087 of 8 March 2006 approving the national hospital hygiene policy document, "Most health centers lack appropriate structures for the collection and treatment of liquid waste (activated sludge treatment or bacterial bed stations). In some cases, liquid wastes are dumped in washbasins and drained to septic tanks. In other cases, they are evacuated directly into the public sewers when they exist, or released into the nature" [9]. When treatment systems exist, studies revealed the inefficiency of the treatments done on the effluents. This is the case, for example, of CNHU-HKM, the largest national hospital. The comparative effluents analysis at the inlet and the outlet of CNHU-HKM treatment station, has shown that chemical and biological treatments are inefficient [10]. Concerning the CHU-MEL, a characterization study of its effluents discharged into the Cotonou lagoon also revealed the inefficiency of treatment processes [11]. The discharge of these effluents into aquatic environments contributes to the pollution of these ecosystems and exposes people to infections caused by multi-resistant microorganisms.

This work aimed to assess the heavy metals content of the CHU-MEL effluents with the goal to evaluate the potential risk of their rejection in Cotonou lagoon.

2. Material and Methods

2.1. Field of Study

The present study is conducted on effluents from the

University Hospital Center of Mother and Child Lagoon (CHU-MEL). This hospital is located in the city of Cotonou at the edge of the Cotonou Lagoon in the commercial area, not far from the Coulibaly Technical High School (Figure 1).

Created in 1958 in the medical district, the CHU-MEL had later been transferred to the site of the former Commercial Energy Distribution Company (CCDEE) in Tokpahoho. Hence its first name was "Maternité TokpaHoho". After, named Hospital of the Mother and Child of the Lagoon (HOMEL), it became University Hospital Center of Mother and Child of the lagoon (CHU-MEL) in 2015. The CHU-MEL is specialized in gynecological, obstetric and pediatric care. It has a capacity of more than 200 beds. The liquid effluents resulting from the various activities of this hospital are drained into the Cotonou lagoon by underground pipes.

Cotonou is the economic capital and the most populated city in Benin. It is located between 6°20' and 6°23' of north latitude and between 2°22' and 2°30' of east longitude. Limited to the west by commune of Abomey-Calavi and to the east by Sèmè-Kpodji. Cotonou has two natural borders connected by a channel (Cotonou lagoon): Lake Nokoué in the North and the Atlantic ocean in the south [12-13].

Due to its geographical situation, the study area is subjected to a subequatorial climate characterized by two rainy seasons (the heavy one from April to July and the light one from October to November). They mark the flood periods of the continental waters. On the other hand it is also characterized by two dry seasons (one from December to March and the second covering the months of August and September) [13] marking periods of low water levels in the lagoon.

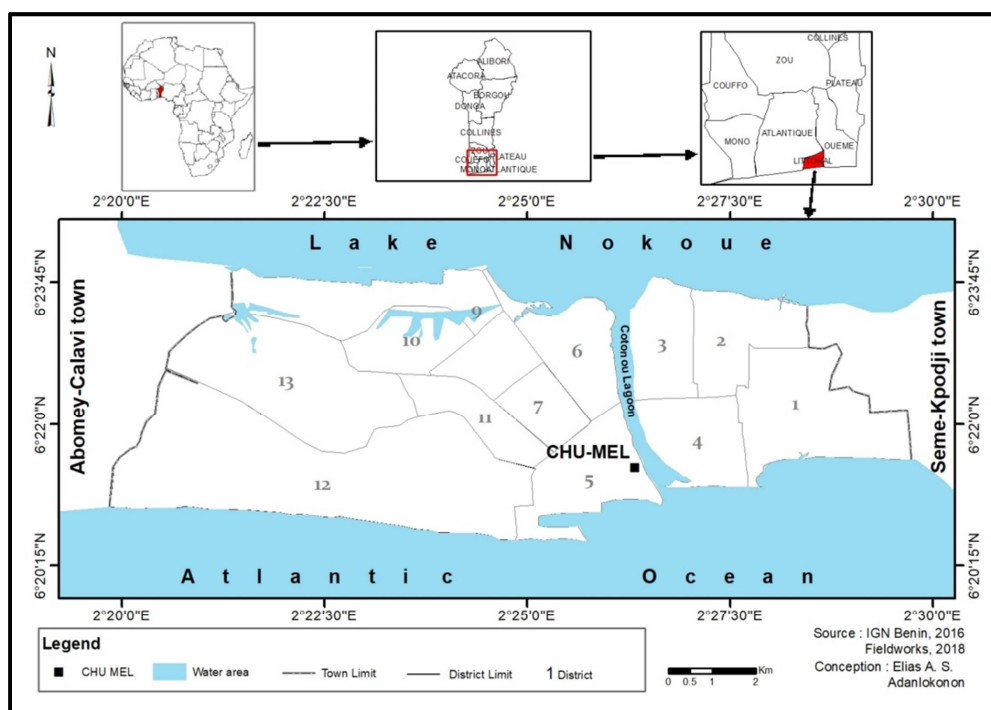


Figure 1. Map of Cotonou town showing the position of the CHU-MEL at the edge of the Cotonou lagoon.

2.2. Sampling and Conservation of Effluents

Four (04) sampling campaigns were conducted in 2018 following the four seasons. Indeed, this work is included in a study on the impact of the CHU-MEL effluents on the zooplankton community of the Cotonou Lagoon, which takes into account the two seasons quoted above. The sampling campaigns took place respectively in January (long dry season (LDS)), in June (long rainy season (LRS)), in August (short dry season (SDS)) and in October (short rainy season (SRS)) of the year 2018. During each campaign, five (05) samples (with the interval of 3 hours between two consecutive samplings) were made between 7 am and 7 pm at the end of the ducts discharging the effluents into the lagoon. This time is the accessible moment to the sampling site.

Samples were taken in polystyrene bottles with a volumetric capacity of 500 mL fully filled, previously washed with distilled water, and after rinsed with effluents (three times). The collected samples were kept in icebox filled of ice to the laboratory for analysis purpose.

At the end of each sampling, all collected samples were gathered in a beaker and then homogenized to obtain a daily composite sample (aliquot). Thus, one (01) daily aliquot of 500 mL is constituted after each campaign. Diluted nitric acid was added to the samples before its storing at 4°C in darkness to ensure stability.

The average amount of effluents discharged into the lagoon has been determined. At each sampling campaign, for

three days taken during the sampling week, we measured the flow of effluent discharged into the lagoon. Three measurements were taken during each day (in the morning between 7 and 8 am, in the afternoon between 12 and 1 pm and in the evening between 6 and 7 pm). A yearly flow average is calculated based on that of campaigns. This operation allowed us to evaluate the load of pollutants discharged into the lagoon per day.

2.3. Analytical Methods

Temperature, pH, electrical conductivity, total dissolved solid (TDS) and dissolved oxygen content of the effluents were measured in situ with the multi parameter HANNA HI 9829. Cadmium, lead and total iron are measured by molecular absorption spectrophotometry (SAM) using the DR 2800 spectrophotometer. The dithizone method has been used to determine cadmium and lead contents. This measurement is performed after sample mineralization (according to HACH). Total iron is determined by the FerroVer method. The mercury content is determined by cold vapor atomic absorption spectrophotometry (SAA) after incineration under oxygen flux (O_2) at 254 nm using DMA-80. The liquid samples are weighed and introduced into the DMA-80. Results are displayed directly on a screen connected to the device and are validated according to the method 7473 of the US. EPA [14].

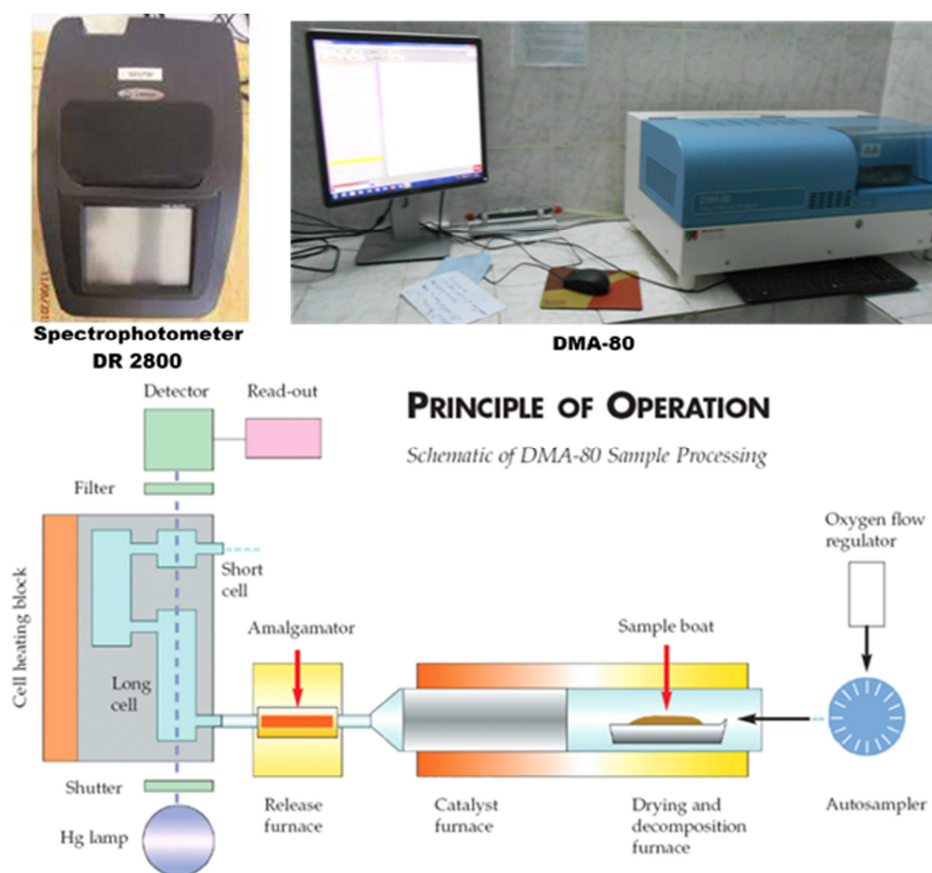


Figure 2. Materials used to dosage of heavy metals.

2.4. Statistical Analyzes

The statistical analyzes and the calculation of means and standard deviation were carried out with STATISTICA software (version 6.1 Statsoft Inc. Tulsa, OK). The Pearson correlation coefficient (r) was calculated to verify the correlation that would exist between physico-chemical and heavy metal parameters [15-16].

3. Results

Table 1 presents the average of the various parameters studied and certain effluents discharge standards in the natural environment.

Most of the parameters (physicochemical and heavy metals) studied except the dissolved oxygen content, are in accordance with wastewater discharge standards [17-20].

Table 1. Averages and standard deviations of physicochemical parameters and measured heavy metals contents compared to some Standards.

Parameters	Unit	Mini	Maxi	Mean & SD	Standards			
					Benin [17]	Egypt [18]	France [19]	Morocco [20]
Temperature	°C	28.52	30.3	29.60 ± 0.7978	-	30	-	30
pH		5.56	10.76	7.95 ± 2.1373	6 - 9	-	-	5.5 - 9.5
Dissolved oxygen	mg/l	0.16	0.25	0.22 ± 0.0395	≥ 5	-	-	-
Electrical conductivity	μS/cm	388.02	1273	639.60 ± 425.81	2000	-	-	-
TDS	mg/l	72.31	1272	457.48 ± 548.99	-	-	-	-
Lead	mg/l	0.0744	0.2956	0.1727 ± 0.1018	1	0.5	0.5	1
Cadmium	mg/l	0.0156	0.0319	0.0261 ± 0.0072	1	0.05	0.001	0.25
Mercury	mg/l	0.0007	0.0012	0.0010 ± 0.0003	0.03	0.005	0.00003	0.05
Total iron	mg/l	0.0500	0.3700	0.2500 ± 0.1407	-	1.5	-	5

SD: Standard Deviation

Table 2. Comparison test of the average of the lead, cadmium and mercury to beneneses standard ($N=4$).

	Mean & SD	Beneneses standard	P
Lead	0.1727 ± 0.1018	1	0.000507
Cadmium	0.0261 ± 0.0072	1	0.000000
Mercury	0.0010 ± 0.0003	0.03	0.005151

3.1. Physicochemical Parameters

Figures (3, 4 and 5) show the respective variation in temperature, pH, conductivity, TDS and dissolved oxygen. Their respective averages are: 29.60 ± 0.80 °C; 7.95 ± 2.14; 639.60 ± 425.81 μS/cm; 457.48 ± 548.99 mg/L and 0.22 ± 0.04 mg/L.

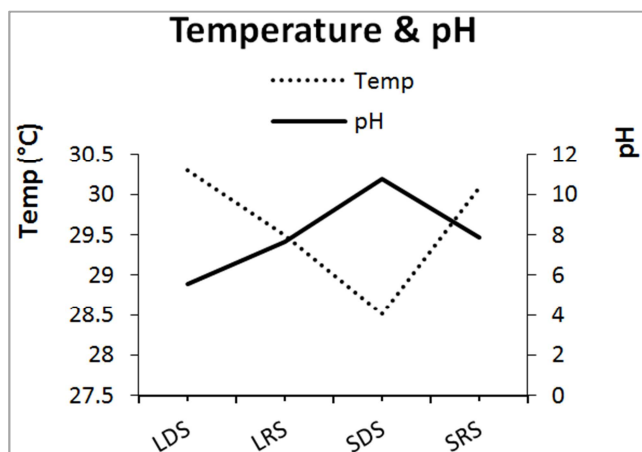


Figure 3. Temperature and pH variation.

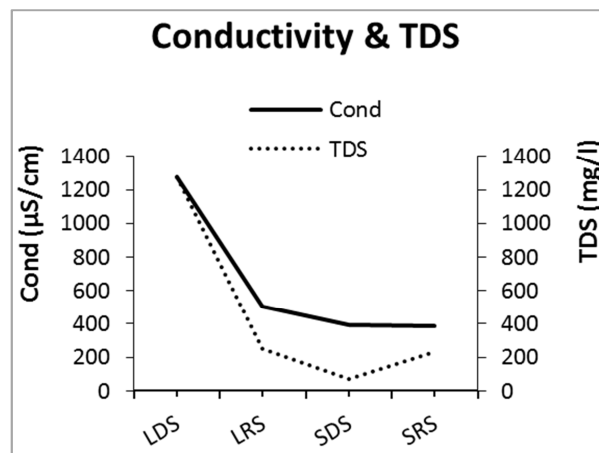


Figure 4. Conductivity and TDS variation.

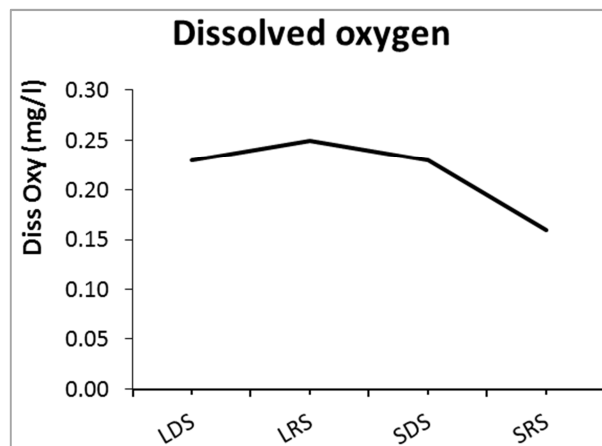


Figure 5. Dissolved oxygen variation.

3.2. The Metal Content

$$Q = 114048 \text{ L/j} \quad (1)$$

3.2.1. Metal Loading in Effluents

To determine the load of metals in the effluents, we first assessed the average amount of effluent discharged per day into the lagoon. We therefore proceeded to the measure of the average flow.

The average flow D measured during our work is 1.32 L/s, what equals to in a daily average effluents quantity of:

$$Q = D * 3600 * 24$$

Each metal load (C) is evaluated as follow:

$$C = \text{Average concentration of metal} * Q \quad (2)$$

These loads and the average concentrations of the various heavy metals are presented in table 3. The average loads are compared to the beninese norms of effluents discharge in natural environments. Sum up, the heavy metals loads in the effluents are in the following order: C(Fe) > C(Pb) > C(Cd) > C(Hg).

Table 3. Average daily concentration and average load of metals contained in the effluents discharged into the lagoon.

Parameters	Means & Standard deviation (mg/l)	Average load (mg/j)	Beneneses standard (mg/j)
Lead	0.1727 ± 0.1018	19698.94±11609.11	5
Cadmium	0.0261 ± 0.0072	2976.65±821.83	5
Mercury	0.0009 ± 0.0002	102.64±22.81	0.1
Total iron	0.2500 ± 0.1407	28512±16047.98	-

The correlation matrix between heavy metals and abiotic variables (Table 4) shows that there is no correlation between the presence of heavy metals in the effluents and these parameters. There is still a significant correlation between electrical conductivity and TDS ($r = 0.99$; $P < 0.01$).

Table 4. Matrix of correlation of physicochemical parameters with heavy metals (N = 04 samples).

Variable	Temp	pH	Cond	TDS	DissOxy	Pb	Cd	Hg	Total iron
Temp	1.00								
pH	-0.92	1.00							
Cond	0.59	-0.79	1.00						
TDS	0.69	-0.84	0.99	1.00					
DissOxy	-0.38	0.00	0.30	0.18	1.00				
Pb	0.04	0.01	-0.56	-0.53	-0.04	1.00			
Cd	0.78	-0.77	0.23	0.30	-0.11	0.63	1.00		
Hg	0.30	-0.09	-0.54	-0.46	-0.50	0.88	0.66	1.00	
Total iron	-0.16	0.26	0.22	0.21	-0.28	-0.91	-0.75	-0.68	1.00

Significant correlations marked at $p < 0.05$

3.2.2. Hazard Assessment

Hazards assessment for aquatic ecosystems of the studied hospital effluents consisted in comparing results obtained with the norms [21] presented in Table 1 for physico-chemical parameters and heavy metals contents. This comparison is showed in Table 5. We have considered the Beninese standard for average measured values (Cp) and the threshold (Vs) ratios (Cp/Vs) calculation. The Cp/Vs ratios are lower than 1 for all physicochemical parameters and heavy metals.

Table 5. Comparison of Maximum Measured Concentrations with Threshold Values Established for Hazard Characterization.

Parameters (mg/l)	Unity	Average Mesured values (Cp)	Threshold (Vs)	Ratio Cp/Vs
Température	°C	29.60	-	-
pH		7.95	6 - 9	< 1
Dissolved oxygène	Mg/l	0.22	≥ 5	< 1*
Electric Conductivity	μS/cm	639.60	2000	< 1
TDS	mg/l	457.48	-	-
Lead	mg/l	0.1727	1	< 1
Cadmium	mg/l	0.0261	1	< 1
Mercury	mg/l	0.0010	0.03	< 1
Total iron	mg/l	0.2500	-	-

* For dissolved oxygen the ratio Cp/Vs should be higher.

When we consider the load of heavy metals (Pb, Cd, and Hg) spilled daily in the lagoon, we notice that the effluents present a great risk for the aquatic organisms (Table 6).

Table 6. Comparison of average load of metals with Threshold Values Established for Hazard Characterization.

Parameters	Average load (mg/j)	Beneneses standard (mg/j)	Ratio Cp/Vs
Lead	19698.94±11609.11	5	3939.788
Cadmium	2976.65±821.83	5	595.33
Mercury	102.64±22.81	0.1	1026.4

4. Discussion

The comparison of the averages of all the parameters with several standards shows that the measured values are consistent, with all considered standards except, the case of dissolved oxygen. The table 2 shows that for lead, cadmium and mercury P is well below 0.05 ($P < 0.05$).

Temperature and pH values being for the most part greater than 15 °C for former and between 5.5 and 8.5 for the later, are favorable to the micro-organisms development [22-23].

The mineralization of these effluents is moderate. Indeed, most of the recorded electrical conductivity values are between 333 and 666 $\mu\text{S}/\text{cm}$ (table 1) except from the first sampling where the recorded value is equivalent in average to 1273 $\mu\text{S}/\text{cm}$ [24]. These values are lower than those obtained by Adanlokonon *et al.* (2018) on the hospital effluents that led them to conclude that CHU-MEL effluents discharged into the Cotonou lagoon are highly mineralized. These differences may depend on the origin of the effluents (the hospital has several medical services) and the timing of their sampling. Indeed, studies have shown that the effluents parameters vary according to the hospitals specificities, the place and even the time of sampling during a day [25-27].

The average value of dissolved oxygen is very low (0.22 mg/l) and even lower than both admitted standard in Benin (5 mg/L) and that one recommended by "L'Ordonnance sur le Déversement des Eaux usées" (ODE) which is 6 mg/L. It is also lower than the critical threshold (4 mg/L) below which, aerobic microorganisms life is threatened [28]. This low oxygenation of water is due to a large consumption of dissolved oxygen by the aerobic bacteria for the degradation of organic matter [29]. It gives the environment an anoxic character and therefore a reductor and an asphyxiating character. Thus, this area could promote the reduction of nitrates and sulphates respectively into nitrites and sulphides. Such a modification may be responsible for the unpleasant odors of the effluents [24]. [11] made the same remarks on the same hospital effluents.

Lead, cadmium and mercury are toxics that can be accumulated in aquatic food products. They can cause a number of disturbances in humans: renal, bone, neurological and / or digestive damages, carcinogenic and/or mutagenic disorders [30-31].

Several studies [4, 6, 21, 32, 33] such as ours, have revealed low levels of contamination of hospital effluents by heavy metals. In addition, the assessment of the hazard (Table 5) due to the discharge of these effluents in Cotonou lagoon has shown that these effluents do not pose a great danger. Indeed, the Cp / Vs ratios are less than 1 for all physicochemical

parameters and heavy metals [21]. However, although these concentrations are low, the continued introduction of heavy metals into the aquatic environment is causing adverse effects on aquatic organisms because of their bioaccumulation and biomagnification properties [34-35]. It is thus important to determine heavy metals load in effluents of CHU-MEL daily discharged in the Cotonou Lagoon. Table 3 shows indeed that, heavy metals (Pb, Cd and Hg) taken into account in this study, have an average charges (19698.94 mg/day; 2976.65 mg/day; 102.64 mg/day) that far exceed the Benin threshold values. The discharge of these effluents into the lagoon presents potential risks for the organisms. It is therefore necessary to evaluate the ecotoxicological risks, as recommend by Emmanuel *et al.* [38]. Nevertheless, these results reveal that the assessed risk is low for aquatic organisms in the receiving environment. The flow of water in Cotonou lagoon being 182 m^3/s during floods and slightly less during the low-water period [36], allows effluents dilution large enough to limit ecotoxicological risk. It should be noticed that, due to the presence of some bio-accumulative and persistent pollutants (some drugs including anti-cancer, certain organochlorine compounds.....), effluents discharged into the lagoon could have very long-term negative impacts for the organisms [3, 37].

5. Conclusion

Heavy metals contents assessment of CHU-MEL effluents and their risks for Cotonou lagoon have been conducted in this study. Results revealed a low level of contamination of CHU-MEL effluents discharged into the Cotonou lagoon by heavy metals (Pb, Cd and Hg) which are considered toxic. This fact added to the dilution effect of the effluents in the waters of the lagoon show that effluents discharge in the lagoon present low risks to the aquatic organisms of the receiving environment. However the continual discharge of these effluents into the lagoon could lead to heavy metal and other persistent pollutants accumulation in the aquatic food chain in fact, that is likely to cause long-term adverse effects on aquatic organisms.

Despite the low concentrations measured, the heavy metal load (Pb, Cd and Hg) discharged daily in the lagoon far exceeds the values accepted in Benin (nearly 4000 times for lead, 600 times for cadmium and more than 1000 times for mercury). This observation poses a real environmental problem as regards the discharge of CHU-MEL effluents into the Cotonou Lagoon. It is therefore necessary to evaluate the ecotoxicological risks of CHU-MEL effluents that are daily discharged into Cotonou Lagoon.

Conflict of Interest

The authors declare that they have no conflict of interest

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