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Characterization of liquid discharges of the Regional Hospital Center of Daloa and sizing of the lagoon treatment plant (Midwest, Côte d'Ivoire)

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Abstract
The Regional Hospital Center of Daloa has a lagoon treatment plant activated in 1996 and of which dimensions are currently below the polluting loads received. This treatment plant is today abandoned in a very advanced state of decay. The wastewater that it received from the various services of Hospital are discharged into the natural environment without preliminary treatment. Concerned about the protection of the environment, the Direction of the Hospital in partnership with the University proposes to characterize the wastewater of the hospital and to resize the lagoon treatment plant. Therefore, a monitoring of physico-chemical parameters (temperature, pH, conductivity, dissolved salt, redox potential, dissolved oxygen, turbidity, COD, BOD_5, N-total, P-total, SO_4^{2-}), the trace metals (ETM) and microbiological parameters (*faecal coliforms* and *enterococci*) of the wastewater is conducted on samples taken for 24 hours in one-hour time steps. Results show that these wastewaters are slightly alkaline and weakly mineralized. The COD/BOD_5 ratio is less than 3, indicating that these effluents are biodegradable. Average values of COD and BOD_5 respectively in the order of 553 mg O_2/L and 220 mg O_2/L are determined. The average nitrogen content is 42.80 mg/L. That of phosphorus is 38.7 mg/L. Trace metals are present in these wastewaters in proportions between 0 mg/L and 10 mg/L. Bacterial loads in *faecal coliforms* and *enterococci* in the order of 106 CFU/100 ml are determined. Pollution is generally high during the day, unlike those observed during the night. A resizing of the lagoon treatment plant is proposed for its rehabilitation.

1. Introduction
The effluents generated by hospital activities may present a potential danger for humans and their environment. This is due to the nature and importance of the specific substances that these effluents contain (drug residues, chemical reagents, antiseptics, detergents, developers and X-Ray Fixers ...). Also, hospitals are heavy users of water. The volumes consumed generally produce pollution flows, reduced to a hospital bed higher than those defined for a population equivalent [1]. In addition, microbiological, toxicological and genotoxic pollution (carcinogenic, mutagenic and toxic to reproduction substances), added to the importance of the volumes of effluents produced, raises several questions about their potential risk for humans and their environment on the one hand and their negative influence on the biological treatment of these releases [2]. Thus, for the sake of sustainable development, managing liquid wastes effectively is an increasingly important concern for the international community as a whole [3]. It is in this context and in the concern of redeveloping its wastewater treatment plant (WWTP) that the Regional Hospital Center (RHC) of Daloa characterizes the liquid discharges produced.

The purpose of this article is to evaluate the pollutant load of the wastewater produced by the Regional Hospital Center services and to propose a design of the treatment plant for a better treatment of liquid waste.

2. Material and Methods

2.1. Description of the study area

The Regional Hospital Center (RHC) of Daloa was built in 1961. It covers an area of 27 hectares. It is limited to the East and West by residential areas, to the North by Modern High Schools 2 and 4, and to the South by a shallow. The Regional Hospital Center has 30 buildings housing care services, medical services, medical technology services, cooking, laundry, mortuary and housing. The capacity of the Hospital is 190 beds and the staff number is 287 composed of doctors, nurses, midwives, administrative officers, general service and maintenance agents, and orderlies. The hospital also has a lagoon treatment plant for wastewater which is in a dilapidated state.

2.2. Wastewater collection and analysis

Sampling with a step of one hour was carried out in the main sewage collector for 24 hours. Similarly, in situ measurements in one hour time steps, using HANNA HI 9828 PH / ORP / EC / OD multi-parameter, allowed the determination of the following parameters: pH, dissolved oxygen, redox potential, dissolved salt levels, temperature, electrical conductivity and turbidity.
Ten (10) composite samples of wastewater (E1 to E10) were constituted (Table 1), according to the intensity of the activities of the Hospital, for the determination at the laboratory of the chemical parameters (COD, BOD_5, total nitrogen, phosphorus total, sulphates, MTEs) and the microbiological parameters (*faecal coliforms*, *enterococci*). The preservation and transport of the samples were carried out according to the standards of the French Association of Normalization [4,5].

Table 1: Summary of distribution of composite samples of wastewater from the Regional Hospital Center of Daloa

N°	1		2		3		4		5		6			7			8			9			10	
H	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5
E	E1		E2		E3		E4		E5		E6			E7			E8			E9			E10	

H: hour; E: sample

The Chemical Oxygen Demand was determined by the potassium dichromate oxidation method (NF T 90-101). BOD is obtained by the manometric method [6]. NTK was assayed by titrimetry after distillation of the selenium mineralized sample (NF T 90-010). Total phosphorus was determined after mineralization of the sample in the presence of sulfuric acid and sodium persulfate (NF T 90.023). The sulphate analysis protocol used is the ion chromatography method (MA 300 - Ions 1.3) of the Center of Expertise in Environmental Analysis of Québec [7].
The metallic trace elements are determined by argon plasma ionization source mass spectrophotometry [7]. The bacterial germs were determined according to the agar incorporation method. EMB and Slanetz Batley agar plates were used respectively for the enumeration of *faecal coliforms* (NF T90-414) and *faecal streptococci* (NFT 90-416).

2.3. Sizing of the lagoon treatment plant

The proposed treatment system consists of three basins arranged in series: an anaerobic basin, an optional basin and a maturation basin. The sizing of basins is done according to Zeghoud [8].

2.3.1. Sizing of the anaerobic basin

The anaerobic basin can reduce 40 to 60% of the initial BOD load with a relatively short residence time. The depth of these basin can range from 2 to 5 m.

2.3.1.1. The residence time of the anaerobic basin

The residence time of the wastewater in the anaerobic basin T_{anb} (expressed in days) is calculated by the following formula:

$$T_{anb} = \frac{1}{\beta \times K} \times \log \frac{BOD_{5\ brute}}{BOD_{5\ anb}}$$

T_{anb}: residence time of wastewater in the anaerobic basin (expressed in days);
β : Coefficient of the lagoon capacity utilization, β = 0,9;
K: constant rate of organic pollutants degradation;
$BOD_{5\ brute}$: BOD_5 of raw sewage;
$BOD_{5\ anb}$: BOD_5 of residual purified wastewater at the outlet of the anaerobic basin.

2.3.1.2. The volume of the anaerobic basin

$$V_{anb} = Q \times T_{anb}$$

V_{anb}: volume of anaerobic basin;
Q: average daily flow at the inlet of the anaerobic basin.

2.3.1.3. The surface of the anaerobic basin

$$S_{anb} = \frac{V_{anb}}{P_{anb}}$$

S_{anb}: surface of anaerobic basin;
P_{anb}: depth of anaerobic basin;
The dimensions of the anaerobic basin are determined according to the ratio length / width = 2.

2.3.2. Sizing of the optional basin

In this type of basin, the surfaces are large and the depth varies from 1 to 2 m. These basin play an important role in the reduction of bacteria as well as the polluting load. This type of basin reduces 30 to 50% of the BOD_5 load. The degree of degradation of the pollutants in the optional pond is adopted equal to 50% of $BOD_{5\ anb}$ for wastewater leaving the anaerobic basin.

2.3.2.1. The residence time of the optional basin

The residence time of the wastewater in the optional basin $T_{ob.}$ (expressed in days) is calculated by the following formula:

$$T_{ob} = \frac{1}{\beta \times K} \times \log \frac{BOD_{5\ anb}}{BOD_{5\ ob}}$$

T_{ob}: residence time of wastewater in the optional basin (expressed in days);
$BOD_{5\ ob}$: BOD_5 of residual purified wastewater at the outlet of the optional basin.

2.3.2.2. The volume of the optional basin

$$V_{ob} = Q \times T_{ob}$$

V_{ob}: volume of optional basin;
Q: average daily flow at the inlet of the anaerobic basin.

2.3.2.3. The surface of the optional basin

$$S_{ob} = \frac{V_{ob}}{P_{ob}}$$

S_{ob}: surface of optional basin;
P_{ob}: depth of optional basin;
The dimensions of the optional basin are determined according to the ratio length / width = 3.

2.3.3. Sizing of the maturation basin

The ripening basin receive the effluents from the optional basin. These are fully aerobic basin, with shallow depths (not exceeding 1.5 m). These basin ensure good elimination of pathogenic elements and thus the treated water will be favorable for possible use in agriculture. The reduction in BOD_5 is much slower than in the other basins. The degree of degradation of the pollutants in the ripening basin is adopted equal to 20% of BOD_{5ob} from the outflow of the optional basin.

2.3.3.1. The residence time of the maturation basin

The residence time of the wastewater in the optional basin T_{ob} (expressed in days) is calculated by the following formula:

$$T_{mb} = \frac{1}{\beta \times K} \times \log \frac{BOD_{5\,ob}}{BOD_{5\,mb}}$$

T_{mb}: residence time of wastewater in the maturation basin (expressed in days);

$BOD_{5\,mb}$: BOD_5 of residual purified wastewater at the outlet of the maturation basin.

2.3.3.2. The volume of the maturation basin

$$V_{mb} = Q \times T_{mb}$$

V_{mb}: volume of maturation basin;

Q: average daily flow at the inlet of the anaerobic basin.

2.3.3.3. The surface of the maturation basin

$$S_{mb} = \frac{V_{mb}}{P_{mb}}$$

S_{mb}: surface of maturation basin;

P_{mb}: depth of maturation basin.

The dimensions of the maturation station are determined according to the ratio length / width = 2.

3. Results and discussion

3.1. Physico-chemical parameters

3.1.1. Parameters in situ

The parameters measured at the study site are: temperature, pH, electrical conductivity, dissolved salts, redox potential and turbidity (Table 2, Figure 1). The wastewater from the Regional Hospital Center of Daloa has an average temperature of 28.1 °C. This temperature increases gradually and reaches a maximum of 32.3 °C to 13 hours and then decreases to 27 °C to 18 hours. Beyond this time, it varies very little up to a minimum value of 25.4 ° C at 5 am (Figure 1-a). The temperature values of these wastewaters vary little and range from 25 to 33 ° C. Temperature plays a role in the solubility of salts and especially gases, in the dissociation of dissolved salts and therefore on electrical conductivity. In the receiving environment these temperatures are favorable to nitrification phenomena. Indeed, nitrification is optimal for temperatures ranging from 28 to 32 °C. On the other hand, it is greatly reduced for temperatures of 12 to 15 °C and stops for temperatures below 5 ° C. The temperature of this wastewater is therefore favorable to lagoon depollution processes [9].

The maximum and minimum pH values are 8.3 and 7.3 respectively, with 7.7 as the average value. These maximum and minimum pH values vary slightly throughout the day (Figure 1-b). The pH of the RHC wastewater indicates a slightly alkaline character (pH> 7). This parameter plays a key role in the growth of microorganisms in the environment for pH values ranging from 6.5 to 7.5 [10].

The electrical conductivity oscillates between a minimum value of 273 µS / cm and a maximum of 563 µS / cm around an average value of 396 µS / cm. In general, the electrical conductivity of these wastewaters decreases from 6 hours overnight to 5 hours (Figure 1-c). The conductivity values oscillate between a minimum value of 273 µS / cm and a maximum of 563 µS / cm with an average value of 396 µS / cm. Conductivity is the mineralization of water associated with the decomposition of organic matter. It is influenced by environmental parameters such as pH, temperature, redox potential, and dissolved oxygen. The recorded conductivity results indicate the onset of water mineralization with dissolved salt levels ranging from 170 mg / L to 349 mg / L. The average values of conductivity between 449.7 µS / cm and 1037.3 µS / cm, highlight a strong mineralization of wastewater [11]. The rate of dissolved salts in these waste waters is on average 246 mg / L. TDS values range from a low of 170 mg / L to a high of 349 mg / L (Figure 1-d).

Table 2: Average, minimum and maximum values of the concentrations of parameters measured in situ

	Temperature °C	pH	Conductivity (µS/cm)	TDS (mg/L)	REDOX (mV)	turbidity (NTU)
Min	25,4	7,3	273	170	-354	17
Average	28,1	7,70	396	246	-323	95,8
Max	32,3	8,3	563	349	-257	214
Standard deviation	2	0,3	76,8	47,7	24,3	44

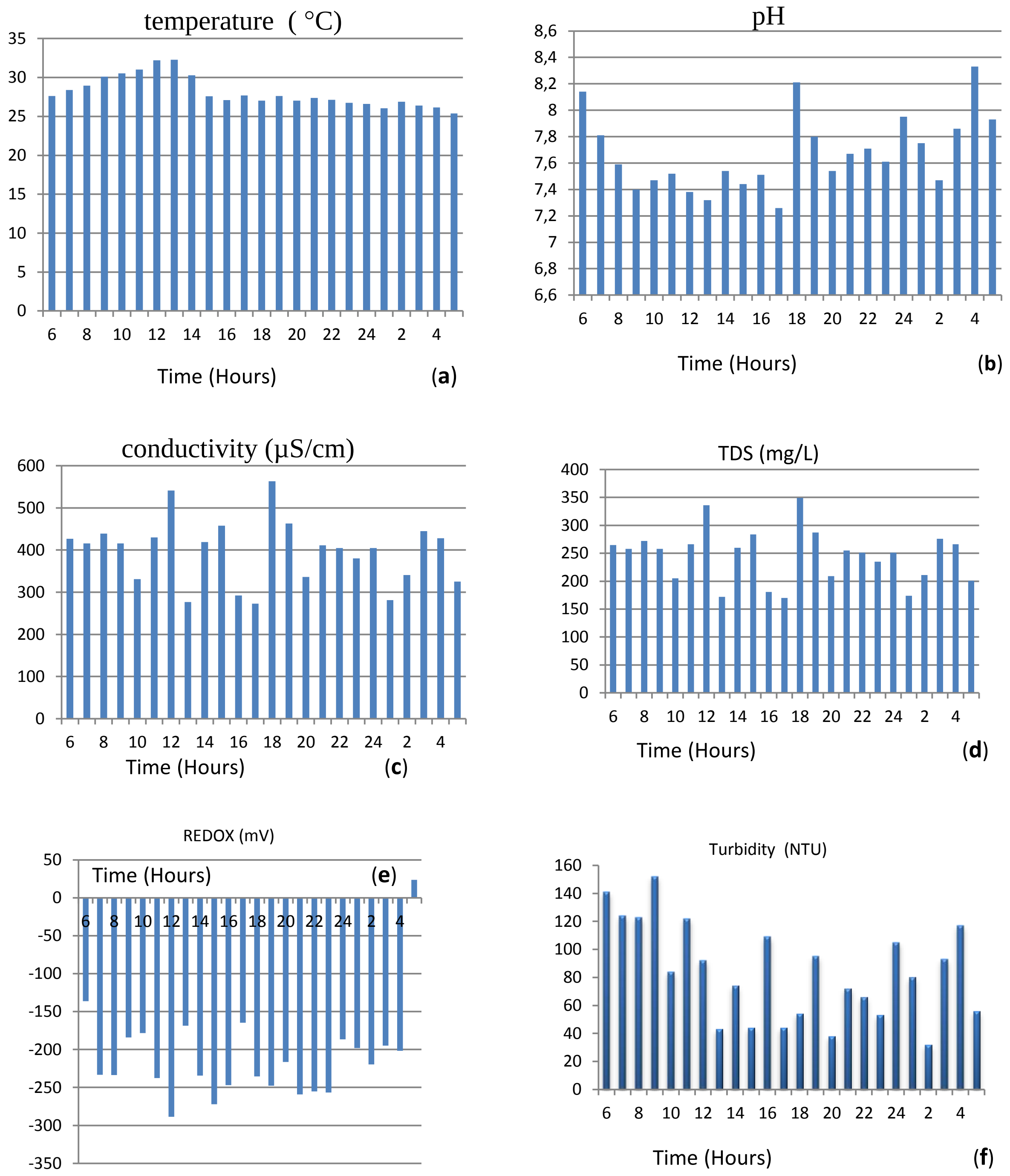

Figure 1: Variation of physico-chemical parameters measured ments in situ of wastewater

The redox potential has a average value of -323 mV with a minimum of -354 mV and a maximum of -257 mV (Figure 1-e). These values are all negative and vary slightly like pH. The redox potential is relatively constant. An average value of -323 mV is recorded with a minimum of -354 mV and a maximum of -257 mV. These values reflect a reducing environment and can have several consequences in the natural environment. Indeed, in addition to the creation of toxic substances, the release of bad odors (hydrogen sulphide) can occur. Also, negative redox potentials accompanied by low dissolved oxygen values can cause significant release of phosphates trapped in the sediment, thus exacerbating eutrophication problems in surface waters [12]. The wastewater from the RHC must necessarily be treated before being discharged into the natural environment.

Turbidity oscillates between a minimum value of 17 NTU and a maximum of 214 NTU with an average value of 95.8 NTU (Figure 1-f). It decreases from 6 am in the morning to 5 hours. Turbidity oscillates between a minimum value of 17 NTU and a maximum of 214 NTU with an average value of 95.8 NTU. It reduces the transparency of the liquid and prevents the propagation of light necessary for photosynthetic phenomena in rivers [13].

3.1.2. Parameters determined in the laboratory

3.1.2.1. Chemical Oxygen Demand and Biochemical Oxygen Demand

The COD values of the composite samples range from 220 mg O_2 / L to 1120 mg O_2 / L with an average of 553 mg O_2 / L. Those of BOD_5 recorded ranged from 88 mg O_2 / L to 446 mg O_2 / L around an average of 220 mg O_2 / L (Table 3). The ratio COD / BOD_5 varies from 2.5 to 2.7 (Figure 2).

Table 3: Average, minimum and maximum values of COD and BOD of wastewater from the Regional Hospital Center of Daloa

	COD (mgO_2/L)	BOD_5 (mgO_2/L)
Min	220	88
Max	1120	446
average	553	220
Standard deviation	283	114

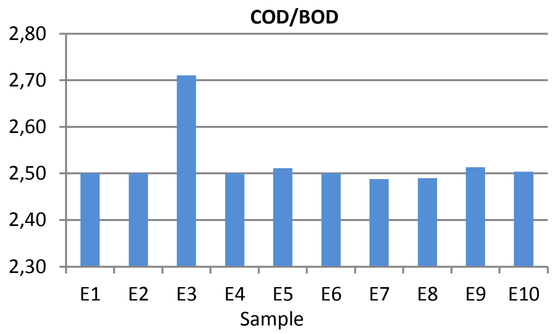

Figure 2: Variation in COD and BOD_5 in wastewater of the Regional Hospital Center of Daloa

The wastewater from the Regional Hospital Center has a COD / BOD_5 ratio ranging from 2.5 to 2.7 in other terms, included in 1 and 3, the range of biodegradable wastewater [14].

3.1.2.2. Concentration of Nitrogen, Phosphorus and Sulfate

The total nitrogen values for RHC wastewater range from a minimum value of 28 mg / L to a maximum of 70 mg / L with an average value of 42.8 mg / L. The highest values are recorded in samples 3, 5 and 7 which represent samples taken from 10 to 11 hours, from 14 to 15 hours and from 19 to 21 hours (Table 4, Figure 3). The total phosphorus content of this wastewater ranges from a minimum of 19.9 mg / L to a maximum of 77.8 mg / L with an average value of 38.7 mg / L. The highest values are recorded in samples 1, 2 and 4 which represent samples taken from 06:00 to 09:00 and from 12:00 to 13:00 (Table 4, Figure 3). Sulphate concentrations range from a minimum of 87 mg / L to a maximum of 186 mg / L with an average value of 109 mg / L. The highest values are recorded in samples 1 to 7, which represent samples taken between 6 am and 9 pm (Table 4, Figure 3).

Table 4: Average, minimum and maximum values for total nitrogen, total phosphorus and sulphate sewage concentrations

	Nt (mg/L)	**Pt (mg/L)**	**SO_4^{2-} (mg/L)**
Min	28,00	19,90	87,00
Max	70,00	77,80	186,00
Average	42,80	38,70	109,03
Standard deviation	14,39	16,44	28,56

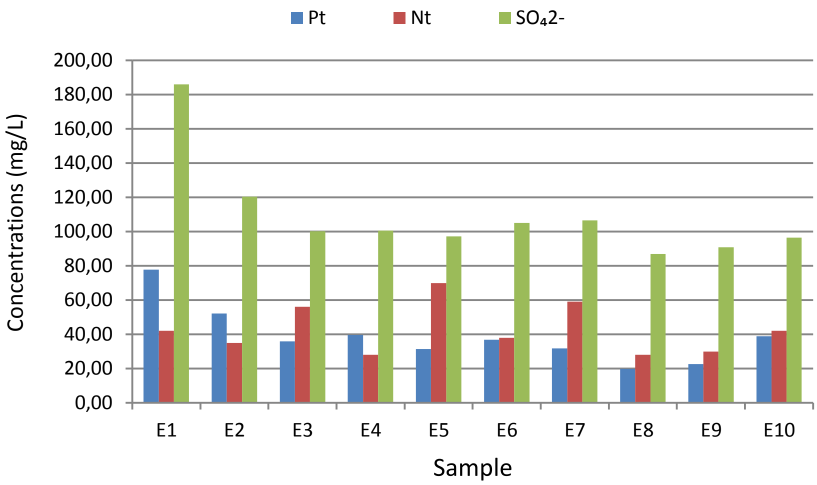

Figure 3: Average variation in total nitrogen, total phosphorus, and sulphate sewage concentrations

3.1.2.3. Concentration in trace metals

Figure 4 shows a relatively constant change in calcium concentrations. Sodium and potassium show similar variations. The sodium concentration is the largest in all samples. The highest values are recorded in samples 1, 2, 4 and 6 which represent samples taken from 06:00 to 09:00, from 12:00 to 13:00 and from 16:00 to 18:00. The lowest levels are recorded for magnesium, cadmium, aluminum and manganese. The average values of these parameters expressed in milligrams per liter evolve in the following descending order: Na> Ca> K> Mg> Cd> Al> Mn (Table 5).

Table 5: Average, minimum and maximum values in mg / L of the metallic trace elements concentrations

Parameters	**Ca**	**Cd**	**K**	**Mg**	**Mn**	**Na**	**Al**
Min	2,37	0,00	1,18	0,19	0,00	4,54	0,05
Max	2,84	0,20	2,45	0,27	0,01	8,80	0,21
Average	2,50	0,07	1,72	0,20	0,00	5,80	0,13
Standard deviation	0,14	0,07	0,40	0,02	0,00	1,28	0,06

The concentrations of Trace Metals the Regional Hospital Center wastewater vary in descending order of contamination: Na> Ca> K> Mg> Cd> Al> Mn. Trace metals are only very weakly volatile and are not biodegradable. These two main characteristics give the Trace metals a great capacity of accumulation in all compartments of the biosphere [15-17].

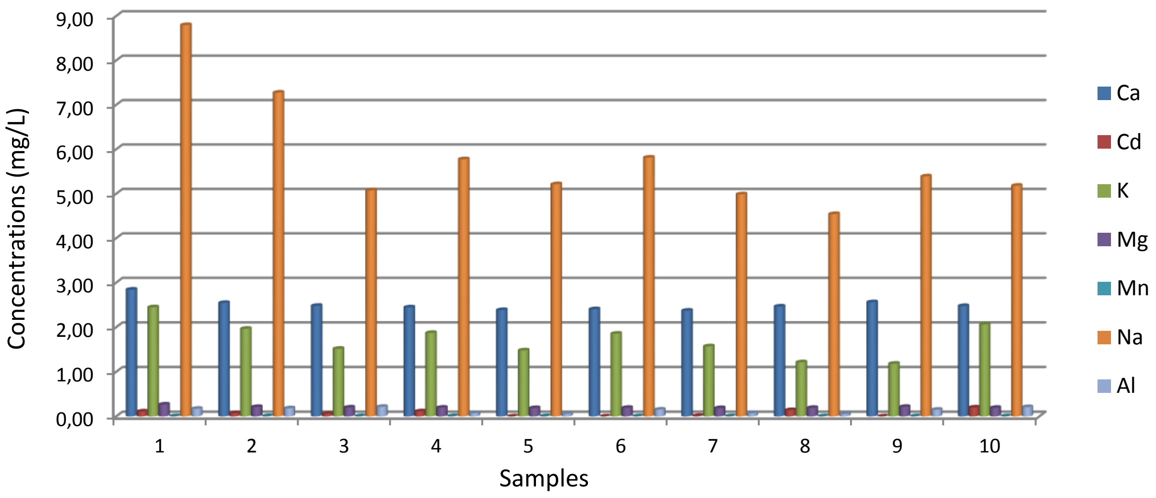

Figure 4: Average hourly change in metallic trace elements concentrations of wastewater

3.2. Microbiological parameters

Bacteriological analysis of the Regional Hospital Center of Daloa wastewater revealed the presence of *faecal coliforms* and *enterococci* in the composite samples studied. *Faecal coliforms* loads ranged from 2.6 to 106 CFU / 100 mL to 19.2 to 106 CFU / 100 mL with an average of 8.03 to 106 CFU / 100 mL. For *enterococci*, the recorded loads ranged from 1.1 106 CFU / 100 mL to 16.3 106 CFU / 100 mL with an average of 5.7 106 CFU / 100 mL (Figure 5).

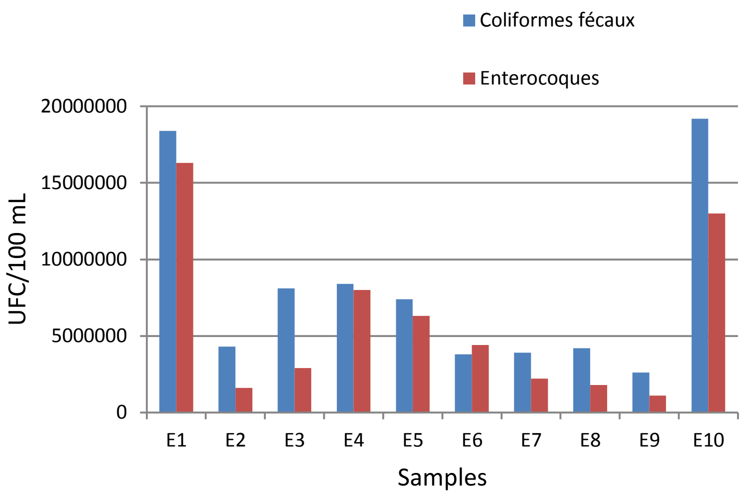

Figure 5: Variation of bacterial loads of wastewater

The highest values are recorded in samples 1, 3, 4, 5 and 10, which represent samples taken from 06:00 to 07:00, from 10:00 to 15:00 on the one hand and, on the other hand, between 4 o'clock and 5 o'clock in the morning. The results obtained show the presence of more *faecal coliforms* than *enterococci* in these wastewaters (Table 6). These wastewaters contain bacterial loads in *faecal coliforms* and *enterococci* in the order of 106 CFU / 100 mL. The average fecal coliform load found at the main RHC collector is 8.106 CFU / 100 mL. That of *enterococci* is 5.7 106 CFU / 100 ml. The *faecal coliforms* load (8.106 CFU / 100 mL) is higher than that obtained by Boillot (2.103 and 2.106 CFU / 100 mL) in the effluents of a hospital in a large city in South East France [18]. According to Literature [19-22], the concentration of *faecal coliforms* in a hospital effluent could give us information on the ecotoxicity rate of this effluent.

Table 6: Average, minimum and maximum values of bacterial loads in wastewater

	Faecal coliforms	*Enterococci*
Min	2 600 000	1 100 000
Max	19 200 000	16 300 000
Average	8 030 000	5 760 000
Standard deviation	6 017 207	5 230 509

3.3. Dimensions of the lagoon treatment plant

The gap between current (actual) and calculated volumes of optional basins and maturation is very pronounced. Indeed, actual volumes represent respectively 26% and 9% of the calculated volumes of the optional pools and ripening (Table 7).

Table 7: Summary of dimensioning results

		Surface (m^2)		**Volume (m3)**	
Basin	**Residence time (days)**	Calculated	Real	Calculated	Real
Anaerobic	7,25	1 087	1 260	3 806	4 410
Optional	9,84	3 935	1 040	5 903	1 560
Maturation	22,84	11 421	1 040	13 705	1 248

The physicochemical and bacteriological characteristics of the RHC wastewater will help to carry out actions aimed at redeveloping the hospital wastewater treatment plant so that the water discharged by the hospital will comply with the standards in force. As a redevelopment action, the realization of complementary basins is necessary to achieve the objectives.

Conclusion

The results of the physico-chemical and bacteriological characterization of the wastewater from the Regional Hospital Center (RHC) of Daloa generally have high values during the day, contrary to those observed during the night. This observation can be justified by the intensification of activities within the Hospital departments during the day.

This study made it possible to determine the physicochemical and microbiological parameters of wastewater from the Regional Hospital Center of Daloa with a view to the redevelopment of those wastewater treatment plant.

The physico-chemical results reveal low values of conductivity (273 - 563 µS / cm), dissolved salt levels (170 - 349 mg / L), redox potential (-354 mV at -257 mV) and a relatively low for temperature (25.4 - 32.2 ° C) and pH (7.3 - 8.3). Values are relatively high for turbidity (17 - 214 NTU), chemical oxygen demand (220 – 1120 mg O_2/L), biochemical oxygen demand (88 – 446 mg O2/L), total nitrogen (28 - 70 mg / L), total phosphorus (19.9 - 77.8 mg / L), sulphates (87 - 186 mg / L) and very low for some ETMs such as cadmium.

Concerning microbiological parameters, the studied effluents contain *faecal coliforms* (2.6 - 19.2 10^6 CFU / 100 mL) and *enterococci* (1.1 - 16.3 10^6 CFU / 100 mL).

The RHC wastewater has favorable COD / BOD_5 ratio for biological treatment. Therefore, these wastewater must be biologically treated before being released into the natural environment. This necessarily involves the redevelopment of the lagoon station.

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