Physico-chemical characterization and assessment of the risk of pollution: A case of wastewater generated by the regional hospital and the central prison of the city of Ngaoundere, Cameroon.

ABSTRACT

Among the public spaces with high human user traffic- schools, hospitals and prisons generate the most volumes of wastewater in developing countries. In addition, when this wastewater is discharged into natural environments without treatment, it can lead to disastrous pollution. The aim of this study is to analyze the physico-chemical parameters of the wastewater of the central prison and the regional hospital in the city of Ngaoundere (Cameroon) and to assess their pollution potential. To achieve this, physical-chemical parameters (temperature; pH; electrical conductivity, total suspended solid; COD, BOD_5; heavy metal content) of water from a control site and wastewater from the regional hospital and central prison were measured and compared to current standards. In order to better assess the risk of pollution, a wastewater quality index (WWQI) and a heavy metal pollution index (HPI) were calculated. It shows that for all physico-chemical parameters studied, the values are above the norm except temperature and pH. With a WWQI of 172.81 from prison's wastewater and of 176.03 from hospital's wastewater, these wastewaters have values above 100 and are therefore highly polluted. The heavy metal pollution index is 37.89 for control water, 183.10 for prison wastewater and 121.14 for hospital wastewater, respectively. Cadmium and especially lead contribute to increasing the heavy metal pollution index in wastewater. Remediation of these waters should therefore focus on these two heavy metals. The above-standard concentrations of some parameters and pollutants as well as the high wastewater quality index and heavy metal index suggest that the discharge of this wastewater into the natural environment without treatment or its direct use as fertilizers constitutes a potential source of pollution of the soil and surrounding vegetation and beyond a threat to human health if these pollutants enter the human food chain.

Keywords: Wastewater, Wastewater Quality Index (WWPI), Metal Pollution Index (HPI), prison, hospital, Ngaoundere.

1. INTRODUCTION

Water is essential for humans and its use generates the production of wastewater. Wastewater refers to any water whose quality has been deteriorated by human activities. In developing countries, entities with a high human concentration such as schools, hospitals and prisons generate large volumes of wastewater. Prisons are generally connected to a distribution network and consume a lot of water. However, the water entering the prison is not only used for the immediate needs of inmates, it must cover other needs [1] such as drinking, meal preparation, maintaining personal hygiene, functioning of sewage and waste disposal systems and keeping the premises clean. Sewage and waste disposal is often the most important health area in places of detention. At their exit, these waters can contain several elements: sand and other suspended solids, pathogenic microorganisms and various chemicals [1]. In Cameroon, there are no national statistics on the sanitation situation of prisons [2].

Hospitals are also a major consumer of water; whereas in a domestic environment consumption is 150 to 200 L per capita per day, the average value increases from 400 to 1200 L in hospitals [3] In addition to this water consumption, there is special water used by the hospital as sterile water [4] Effluents generated by hospital activity may present a potential hazard for the hospital and its environment in view of the nature and importance of the specific substances they contain (drug residues, chemical reagents, antiseptics, detergents, radiographic developers and fixators) and because of their disposal, in the same way as conventional urban discharges, to the communal sewerage network without prior treatment [4]. The characteristics of hospital wastewater are very varied. They may contain detergents, organic matter, biological fluids, chemicals and biologicals, radionuclides [5, 6].

The aim of this study was to characterize the wastewater from two facilities that use large volume of water every day, the hospital and the prison, and to assess its pollution potential by comparing it with control water and calculating its heavy metal pollution index.

2. MATERIAL AND METHODS

2.1. Study area and sampling sites

Error! Reference source not found. shows the geographic location of the study area and the three main water sampling sites. Wastewaters from the central prison and the Ngaoundere regional hospital were compared with the water of control site located near the post office. This control site is located downstream of two sites mentioned and is not subject to any pollution. Three repetitions were performed and averages were obtained.

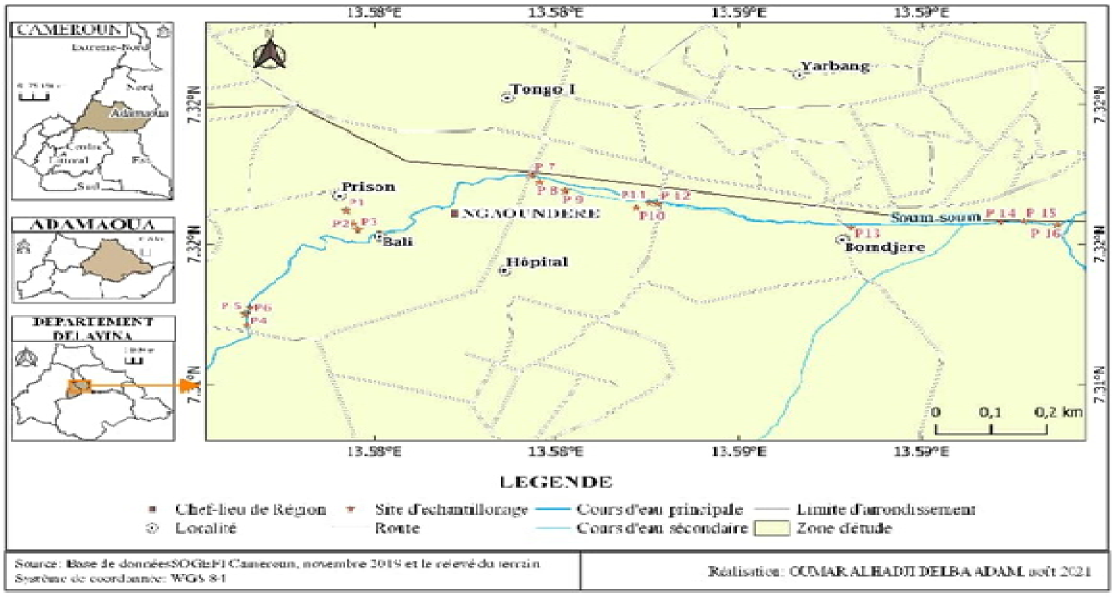

Figure 1: Geographical location of sampling sites.

2.2. Sampling and storage of samples.

We used 0.5-litre bottles and a ladle for easy filling to collect and store the samples. The instrument was rinsed three times with the polluted wastewater before sampling. Once taken, the bottles containing the samples were clearly labelled, then packed in black plastic and relabelled and kept cold in cool box containing ice cubes.

2.3. Pollution indicator parameters used.

The temperature, pH and conductivity of the water samples were taken in situ and the reading was done after immersion and homogenization for 10 minutes of the sampled water [7]. Turbidity was measured by dispersing suspended particles by light at an angle of 90° using the multiparameter PCE-PHD1. BOD_5 was determined using an *Oxytop* which heads to measure the differences in partial pressure of O_2 et CO_2. and COD by colorimetric determination with potassium dichromate after treating the wastewater with potassium dichromate, residual potassium dichromate is measured colorimetrically [8]. Heavy metals were determined by atomic absorption spectrophotometry. The concentrations were analysed using an atomic absorption spectrophotometer (AAS), model of VARIAN Spectr AA.20.

2.4. Data analysis.

Statistical analyses were performed using Stat graphics Centurion software, version XVI. Means were compared using analysis of variance (ANOVA) to determine whether the differences were significant. The Schaffer test was chosen to determine the difference between the means of the treatments. The

ANOVA was performed at the 1% significance level.

Two indices were used to assess the wastewater from the three study sites. The wastewater quality index (WWQI) was used for parameters other than heavy metal according to the method recommended by various authors [9–12] This index is used to assess the overall quality of the water. When the index is greater than 100, the water quality is very poor [9–11]. The WWQI is obtained from the following equation:

$$WWQI = \sum \frac{Q_i * W_i}{W_i} \quad (1)$$

Avec W_i is the unit weight for each water quality parameter;
Q_i is the quality rating scale for each parameter.
Q_i is calculated from the following equation:

$$Q_i = \frac{C_i}{S_i} * 100 \quad (2)$$

Where C_i=concentration obtained from the sample;

$$W_i = \frac{1}{S_i} \quad (3)$$

S_i= Standard value, represents the ideal model value of analysed water parameter

The heavy metal pollution index (HPI) was calculated using heavy metal concentration values from three study sites and according to the method used by [13–16]. For these authors, the HPI of the water must have a value of less than 100 for it to be qualified as non-polluted.
the Heavy metal Pollution Index (HPI) model proposed is given by:

$$HPI = \frac{\sum_{i=1}^{n}(W_i - Q_i)}{\sum_{i=1}^{n} W_i} \quad (4)$$

Where, Q_i=Sub index of the parameter;
W_i= the unit weight of the parameter and n is the number of parameters considers.

The sub-index (Q_i) of the parameter is calculed by:

$$Q_i = \left(\frac{|M_i - I_i|}{S_i - I_i}\right) * 100 \quad (5)$$

M_i= Monitored value of heavy metal of the parameter;
S_i= Standard value of the parameter;
I_i= Ideal value of the parameter.

3. RESULTS AND DISCUSSION

3.1. Physico-chemical parameters of wastewater

Table **1** presents the averages of the physical-chemical parameters studied. The water temperature in the different sampling points varied between 22.9±0.0 and 23.5±0.1°C with the high value of the control zone (river water). The temperature of the different sampling points is below the standard value of wastewater in Cameroon. Analysis of variance showed a significant difference for temperature (*F*=61.75; *P*=0.0,001<0.01). The Scheffe multiple range test reveals that the means water temperatures of the control site differ from the prison and hospital wastewaters.

Table 1: Some physico-chemical parameters and organic pollution.

Parameters	Control water	Prison's wastewater	Hospital's wastewater	Norm Cam/WHS	p
Temperature (°C)	23.5 ± 0.1^b	23.13 ± 0.05^a	22.9 ± 0.0^a	<30	*
pH	6.73 ± 0.10^a	7.21 ± 0.50^a	6.82 ± 0.29^a	6-9	
Conductivity (µs/cm)	$161.33\pm0{,}57^a$	489.6 ± 319.2^a	429.33 ± 238.24^a	<2000	*
TSS (mg/L)	7.01 ± 0.11^a	675 ± 2^c	365 ± 6^b	50*	*
COD (mgO_2/L)	3.99 ± 0.3^a	890 ± 11^b	949 ± 67^c	<250	*
BOD_5 (mgO_2/L)	2.35 ± 0.6^a	584 ± 62^b	663 ± 55^c	<50	*
COD/BOD_5	1.68 ± 0.14^c	$1.52\pm0{,}16^b$	1.43 ± 1.26^a	-	*
TSS/BOD_5	2.98 ± 0.12^c	$1.15\pm0{,}01^b$	0.55 ± 0.02^a	-	*

*Cam=Cameroon; TSS=Total Suspended Solids; COD=Chemical oxygen demand; BOD_5=Biochemical Oxygen Demand in 5 days; p=probability at 99%; * significant probability of 99%. The values assigned to the same letter are not statistically different at the 99% probability.*

The hydrogen potential (pH) of the various sampling sites varied in the different sampling points between 6.73±0.10 and 7.21±0.50. The pH values of the control area and hospital waters are in the neutral range, while the pH value of the prison waters is in the alkaline water range. Analysis of the variance in pH (*F*=1.63; *P*=0.27<0.01) reveals that there is no significant difference between the three study sites. The measured values of electrical conductivity (EC) obtained ranged from 161.33±0.57 and 489.66±319.20 µs/cm. There was no significant difference in electrical conductivity between the different sites (*F*=1.7 3; *P*=0.254>0.01). The Total suspended solids (TSS) studied varied between 7.01±0.11 and 675.67±2.87 mg/L. Water of the control zone have a concentration of 7.01±0.11 mg of TSS/L, the wastewater of the Prison and the Hospital have respectively 675.67±2.87 mg of TSS/L and 365.74±6.15 mg of TSS/L. As for the analysis of variance of the total suspended solids content, there was a significant difference the water of the three sites (*F*=21807; *P*=0.000<0.01). Scheffe's test distinguishes three distinct groups.

Water temperature is an important factor in organic production because it affects, among other things, the speed of chemical and biochemical reactions [17].The results obtained corroborate with those obtained by [18]. The temperature value obtained from the prison's and hospital's wastewater are within the range of the recommended discharge standard (30°C) by the Ministry of the Environment, Nature Protection and Sustainable Development (MINEPDED). The temperature at the hospital wastewater (22.9±0.0°C) lower than the 28.28±1.8°C found by [19] on the wastewater of the Yaoundé University Hospital. The temperature at the prison level (23.13±0.05°C) lower than the results obtained by [20] at the Ouagadougou Prison (*maco*) in Burkina Faso.

The hydrogen potential (pH) determines the solubility of metals in water [21].The results obtained in this work are lower than those in year 2020 [22]. This difference in pH would be due to the sampling period and the climate prevailing at these periods (temperature, humidity) in the study area. Based on the results obtained, the pH of the waters in the control area is in line with those recommended by WHO (6.5<pH<8.5). These results corroborate those obtained by [18] his work on the waters of the rivers of Ngaoundere. The pH values obtained for prison water and hospital water respectively 7.21 (alkaline) and 6.82 (neutral) are within the recommended discharge standard (6.5-8.5) by the Ministry of the Environment, Nature Protection and Sustainable Development (MINEPDED). These values also comply with the irrigation water standards recommended by FAO and WHO for wastewater reuse. The pH value obtained at prison water level is lower than the values (8.95 and 8.94) obtained by [20] at the Ouagadougou Prison (*Maco*) in Burkina Faso. The pH value obtained at the level of the hospital water is lower than the 7.4±0.3 with those found by [19] at the level of the wastewater of the university hospital in Yaoundé. This pH is favourable for the growth and survival of microorganisms [23].

Electrical conductivity is used to determine the ability of water to conduct electricity. Indeed, it makes it possible to judge the amount of salts dissolved in the water and to verify the existence of pollution in the water [24] According to the results obtained, the observed values of electrical conductivity are 161.33 µs/cm for the waters of the control zone. This value is between 100 and 200 µs/cm, which reflects a low mineralization and therefore a low amount of dissolved salts. Waters with a conductivity of less than 200 µs/cm, and as such considered to be weakly mineralized waters [7, 25]. These results corroborate those obtained by [18] his work on the waters of the rivers of Ngaoundere. At the sampling points of the Prison and Waters of the hospital, the conductivity is between 333 µs/cm and 666 µs/cm which reflects an accentuated average mineralization which also reflects an accentuated average content of mineral substances and also of metallic trace element. The values obtained at the prison level (489.66 µs/cm) are higher than the 181.85 µs/cm of the Annex Building and lower than the 525.53 µs/cm of the Grand Building obtained by [20] at the Ouagadougou Prison (*Maco*) in Burkina Faso. The values obtained at the hospital wastewater (429.33 µs/cm) are higher than the 340.2 ± 210.2 µs/cm on the analysis of the [26] metal load in the waste water of *chaâb Roba* . The conductivity values obtained at the prison and hospital level are well above the WHO standard (dS/m<3) for wastewater reuse in crop irrigation.

Total suspended solids (TSS) represents all mineral and organic particles contained in wastewater [7] Suspended solids are involved in water composition through their ion exchange or absorption effects on both trace chemical elements and microorganisms [17]. The values of the TSS obtained at the level of the waters of the control zone (river water) is 7.01 mg of TSS/L this value is lower than the standards for discharge into watercourses which is of the order of 20 to 30 mg of TSS/L [27]. These results corroborate those obtained by [18] his work on the waters of the rivers of Ngaoundere. The TSS content obtained in the wastewater of the Prison and the hospital exceeds within the limit value of the MINEPDED discharge standards (≤30 mg TSS/L) for wastewater discharges. The content obtained of 949.72±6.38 mg of TSS/L at the hospital level is higher than the 111.7±67.3 mg of TSS/L obtained by [19] at the wastewater level of the university hospital in Yaoundé. The value of 890.78±11.34 mg of TSS/L obtained at prison water level is lower than the 1583 mg of TSS/L obtained by [20]at the Ouagadougou Prison (*Maco*) in Burkina Faso. The values of the TSS obtained are well above the WHO standard (100-350 mg/L) for wastewater reuse in crop irrigation.

Turbidity is the measure of the cloudiness of water or the reduction of the transparency of a liquid due to the presence of undissolved matter. It is caused in water by the presence of fine suspended solids (TSS) [28] Based on the results obtained; the observed turbidity values at the control zone is 2.93±3.15 NTU (NTU<5), this value allows us to qualify this water as "Clear Water"; according to the WHO standard. These results corroborate those obtained by [18] his work on the waters of the rivers of Ngaoundere. Hospital waters can be described here as "slightly cloudy water" because the turbidity value (28.80±19.84 NTU) is between 5<NTU<30. The turbidity at the level of the Prison Waters (139.62±131.16 NTU), is highly high (NTU>50), these waters can be described as "Troubled Waters". Due to suspended solids, wastewater will have higher turbidity. TSS have a direct impact on the environment through increased turbidity. Turbidity reflects the presence of foreign matter suspended in the water, in fact according to [29] high turbidity of the water reveals the following problems: precipitation of iron, aluminium or manganese due to oxidation in the network; precipitates formed by the effect of post-flocculation in the network (persistent flocculant force and incomplete polymerization) degrade organic quality and this is the case for our waters of the Prison and more or less of the hospital.

COD and BOD_5 make it possible to determine the impact of an effluent on the receiving environment. [22] also has elevated BOD_5 values in these waters. According to the results obtained from the BOD_5 content, the value obtained from the waters in the BOD_5 control zone (2.35 mg/L) and the COD (3.99±0.33 mg/L) are in the range of the standard of 4 to 6 mg O_2 per liter characteristic of good quality water (WHO, 2012). The Prison's BOD_5 value (584.75±62.49 mg/L) is lower than the total BOD_5 concentrations of 2095 mg/L obtained by [20] at the Ouagadougou Prison (Maco) in Burkina Faso. The value obtained at the hospital level (2063.78±155.03 mg/L) is much higher than the 890.4±347.8 mg/L obtained by [19] at the wastewater level of the university hospital in Yaoundé. These results show that these waters are heavily polluted by organic matter and far exceed the organic matter levels allowed by the MINEPDED discharge standard, which sets a value of less than ≤ 100. And these values are also higher than the range (110–400 mg/L) of BOD_5 of the WHO standard for wastewater use in agriculture.

COD makes it possible to assess the concentration of organic or mineral matter, dissolved or suspended in water, through the amount of oxygen necessary for their total chemical oxidation[30] COD values are similar to those obtained by [22] in the same waters. The COD values obtained in prison wastewater (890.78±11.34 mg/l) are lower than the 3148 mg/l obtained by the Ouagadougou Remand and Correction Centre (MACO) in Burkina Faso obtained by [20] The concentration 949.72±6.38 mg O_2/L obtained at the level of the wastewater of the Hospital are lower than the 2240.5±2309.7 mg/L obtained by [19] at the level of the wastewater of the University Hospital in Yaoundé. However, these values are higher than the MINEPDED release standard which sets a value below ≤200. This result shows that these waters are highly loaded with biodegradable and non-biodegradable organic matter (COD) well exceeding the average permissible value of 120 mg O_2/L of organic matter allowed in watercourses and therefore cannot be discharged into the natural environment without prior treatment.

3.2. Parameters of organic wastewater pollution.

The results of the various parameters studied relating to organic pollution are also given in

Table **1**

Table **1** presents the averages of the physical-chemical parameters studied. The water temperature in the different sampling points varied between 22.9±0.0 and 23.5±0.1°C with the high value of the control zone (river water). The temperature of the different sampling points is below the standard value of wastewater in Cameroon. Analysis of variance showed a significant difference for temperature (*F*=61.75; *P*=0.0,001<0.01). The Scheffe multiple range test reveals that the means water temperatures of the control site differ from the prison and hospital wastewaters.

Table 1: Some physico-chemical parameters and organic pollution.

The Chemical Oxygen Demand (COD) content obtained in the different waters varied between 3.99±0.33 and 949.72 mg O$_2$/L. the average COD content obtained at the level of the waters of the control zone is 3.99±0.33 mg O$_2$/L, at the level of the Prison this COD content is 890.78±11.34 mg O$_2$/L and finally at the hospital level 949.72±6.38 mg O$_2$/L. COD analysis (*F*=363; *P*=0.000<0.01) reveals a significant difference with three distinct groups.

The 5 days Biochemical Oxygen Demand for (BOD$_5$) values obtained in the different sampling points ranged between 2.35±0.61 and 2063.78±155.03 mg O$_2$/L. In the control area, the BOD$_5$ concentration is 2.35±0.61 mg O$_2$/L, while wastewater from the Prison and the Hospital had BOD$_5$ concentration of 584.75±62.49 mg O$_2$/L and 6 63.78±55.03 mg O$_2$/L respectively. There was a significant difference between the different sampling sites (*F*=14889; *P*=0.000<0.01).

The COD/BOD$_5$ ratio ranged from 1.43±1.26 to 1.68±0.46. This ratio was around 1.6 8±0.4 6 for the waters of the control area, 1.52±0.16 for the waters of the prison and 1.43±1.26 for the waters of the hospital. The TSS/BOD$_5$ ratio varied between 0.55±0.02 and 2.98±0.12. This ratio is in the order of 2.98±0.12 for the waters of the control area, 1.15±0.01 for the waters of the prison and 0.55±0.02 for the waters of the hospital. Finally, the analysis of variance of the COD/BOD$_5$ ratio (*F*=144; *P*=0.000<0.01) and TSS/BOD$_5$ (*F*=311; *P*=0.000<0.01) showed significantly from three distinct groups representing the three sites studied.

For a better assessment of the origin of wastewater, the calculation of the COD/BOD 5 and TSS/BOD$_5$ ratios and the estimation of the organic matter (OM) is of very important interest. The use of these characterization parameters is a good way to give a good representation of the degree of wastewater pollution. The COD/BOD$_5$ ratio is important for the definition of the effluent treatment chain. Indeed, a low value of the COD/BOD$_5$ ratio implies the presence of a large proportion of biodegradable materials and makes it possible to envisage biological treatment. Conversely, an important value of this report indicates that a large part of the organic matter is not biodegradable and, in this case, it is preferable to consider a physical-chemical treatment [31] The COD/BOD$_5$ ratio makes it possible to deduce whether the wastewater discharged directly into the receiving environment is of domestic origin. The mean COD/BOD$_5$ ratio for control area and hospital waters is lower (0.58±0.14 and 0.65±0.06) than 2, indicating that predominantly domestic effluent is readily biodegradable [7] The value of this ratio is between 2<COD/BOD$_5$<3 characteristics of biodegradable food industry effluent. This ratio is 0.65±0.06 for hospital waters, which reflects a low biodegradability of the substances contained in these effluents. Hospital effluents generally have a very low microbiological load resulting from the regular use of disinfectants. These results are identical to those obtained by [32] on the chemical, biological and ecotoxicological characterization of hospital effluents. This result obtained is confirmed by the OM estimate, which is of the order of 1321.07±53.33 mg/L Prison Water and 788.77±27.27 mg/L Hospital Water with an average ratio of SOW/BOD$_5$ of 0.71±0.0 and 0.41±0.02 respectively. The organic load is marked by very high values of BOD$_5$, COD, organic matter (OM). Nevertheless, overall, the values obtained show a very high organic load and confirm that these wastewaters are easily biodegradable.

3.3. Heavy metals content.

Table **2Table 4** presents the concentration of different heavy metals present in the study area.

Table 2: Concentration of different heavy metals.

Parameters	Control water	Prison's wastewater	Hospital's wastewater	Norm Cam/WHO	p
Cadmium (µg/L)	0.06 ± 0.03^{a}	3.90 ± 1.63^{c}	4.71 ± 0.98^{b}	0.01	*
Copper (µg/L)	9.61 ± 0.44^{a}	41.03 ± 1.92^{b}	93.16 ± 2.21^{c}	0.06	*
Iron (µg/L)	801.177 ± 66.89^{b}	389.35 ± 5.37^{a}	522.62 ± 72.85^{a}	0.2	*
Lead (µg/L)	2.79 ± 0.28^{a}	426.67 ± 4.03^{c}	253.75 ± 15.42^{b}	0.1	*
Zinc (µg/L)	0.65 ± 0.21^{a}	19.66 ± 5.59^{ab}	37.18 ± 8.67^{b}	1	*

*Cam=Cameroon; p=probability at the 99%; * significant probability of 99%*
The values assigned to the same letter are not statistically different at the 99%.

The concentration of Cadmium (Cd) in the waters sampled ranged from 0.06±0.03 µg/L to 124.90±1.62 µg/L. The concentration of Cd in the control waters is 0.06±0.03 µg/L, the concentration in prison effluent is 124.90±1.62 µg/L, and the hospital effluent concentration is 80.71±0.98 µg/L. The concentration of Copper (Cu) in our sampled waters ranges from 9.61±0.44 µg/L to 41.03±1.92 µg/L. The concentration obtained at the control water level is 9.61±0.44, µg/L The concentration in prison and hospital effluents is 41.03±1.92 µg/L and 93.16±2.21 µg/L, respectively. The highest concentration is recorded in hospital waters. The concentration of Iron (Fe) in the waters sampled ranged from 389.35±5.37 µg/L to 801.17±66.89 µg/L. The concentration of iron at the control water level is 801.17±66.89 µg/L, the concentration at the hospital effluent level is 522.62±72.85 µg/L and at the prison level is 389.35±5.37 µg/L. The highest concentration is recorded at the control waters. The concentration of lead recorded in the control waters is 2.79±0.28 µg/L, the concentration obtained in the prison waters is 426.67±4.03 µg/L and that obtained in the hospital waters is 253.75±15.42 µg/L. The highest concentration is recorded at the level of the waters of the Prison. The concentration of zinc obtained in the waters sampled ranged from 0.65±0.21 µg/L to 37.18±8.67 µg/L. The concentration obtained at the control water level is 0.65±0.21 µg/L, in the prison waters the concentration is 19.66±5.59 µg/L, the Zinc (Zn) concentration obtained at the hospital water level is 37.18±8.67 µg/L. The highest concentration is obtained at the level of the hospital waters. Analysis of variance shows a significant difference for all heavy metals studied with for Cd (F=9985.09; P= 0.000<0.01), Cu (F=1822.09; P=0.000<0.01), Fe (F=40.5; P=0.003<0.05); Pb (F = 1607.35; P=0.000<0.01) and for Zn (F=28.18; P=0.0009<0.05). The Scheffe test differentiates three distinct groups for the concentration of Cadmium, Copper and Lead and two groups for the concentration of Zinc and Iron.

The results obtained from the determination of heavy metals in water at the three sampling sites show that the concentration of all heavy metals analysed in control waters is below the standard except for the concentration of Iron which exceeds the WHO standard (300 µg/L). These results corroborate those obtained by [22] in the same waters. Pouring into the soil without treatment, these waters will affect the soil indeed high concentrations of iron make the soil reddish and reduce crop yields. The high iron content in the waters of the control zone is explained by soil erosion in the zone [18].

The concentration of heavy metals (copper, nickel and zinc**)** in prison water is below the WHO standard of 2000 µg/L for copper and zinc [33] While the concentration of cadmium, iron and lead are high disappointed with the standard of 3 µg/L for cadmium, 300 µg/L for iron and 10 µg/L for lead respectively **(**WHO, 1996). These high concentrations in prison water are due to the fact that anthropogenic activities such as the burning of fossil fuels, the incineration of household and industrial waste could lead to an increase in heavy metal concentrations in environmental compartments (air, water, soil). Among the various metallic elements emitted into the environment during anthropogenic activities, zinc, lead, cadmium and copper are the most commonly measured in environmental studies because of the diversity of emission sources [34].

The presence of heavy metals in hospital effluents is related, among other things, to the presence of iodinated contrast agents used for radiography, certain drugs and their metabolites that may contain organo-halogenated elements, the use of disinfectants, detergents and chlorinated solvents, and other substances from laboratories. The high concentration of cadmium in hospital effluents is due to its use as pigments, electroplating and stabilizers [34].

The concentration of Copper, Zinc in hospital waters is below the norm (copper 2000 µg/L and Zinc 3000µg/L). Copper naturally exists in large quantities in the earth's crust. It is used in the composition of many equipment. This high level of wastewater from the hospital and prison could be the result of corrosion of the piping or pollution by hospital products.
The concentration of cadmium, iron and lead is above the norm (3 µg Cd/L, 300 µg Fe/L, and 10 µg Pb/L). The high cadmium content may be due to cleaning activities that use large volumes of detergents, the use of dyeing products during the rehabilitation of treatment rooms, and the absence of pre-treatment of effluents at the service level prior to their disposal into septic tanks. The high iron content in the water is explained by the erosion of the soil in the area and on the other hand by the contribution of pollutants of domestic origin.

The quantitative distribution of metal contents in the sampled waters is as follows: Control water: Fe>Cu>Pb>Zn>Cd; for Prison wastewater: Pb>Fe>Cu>Zn>Cd and those of Hospital wastewater: *Fe>Pb*>Cu>*Zn>Cd*.

3.4. Assessment of pollution potential

Table 3 presents the overall wastewater quality index (WWQI) for the different sites in the study area. The value of the overall water quality index is 99.13 for the control site (river water) against 172.81 and 176.03 respectively for wastewater from the central prison and the regional hospital of Ngaoundere. Based on the water classification, we notice the waters of the river with values below 100, are good, those of prison and hospital sewage with values above 100 are classified as of very poor quality. The fact that the hospital's sewage quality index is higher than that of the prison can be explained by the geographical position of this site in relation to it. Indeed, the hospital site is located upstream of that of the prison and a quantity of pollutants from the prison's wastewater end up in the hospital's wastewater.

Table 4 presents the heavy metal pollution index (HPI) of the different sites and the contribution of the pollutants studied to pollution. The index of heavy metal pollution of river water is 37.89 compared to 183.1 and 121.14 respectively for prison and hospital wastewater. The waters of the river are lightly loaded with heavy metals unlike the sewage of the prison and hospital. Two metals (cadmium and lead) mainly contribute to this type of pollution regardless of the waters studied. Heavy metals such as copper; zinc and iron have HPI values below 1 in the waters studied and do not contribute to pollution. The high value of cadmium in the waters studied can be explained by the proximity of all these wastewaters to landfills rich in used batteries where leaching and leaching of pollutants can take place [35].

Table 3: Wastewater Quality Index (WWQI) values of the different samples.

			Control Water			Prison's Wastewater			Hospital's wastewater		
Parameters	**S_i**	**$W_i=1/S_i$**	**C_i**	**$Q_i=100*(C_i/S_i)$**	**W_i*Q_i**	**C_i**	**$Q_i=100*(C_i/S_i)$**	**W_i*Q_i**	**C_i**	**$Q_i=100*(C_i/S_i)$**	**W_i*Q_i**
Temp (°C)	30	0.03	23.5	78.33	2.61	23.13	77.10	2.57	22.9	76.33	2.54
pH	7.5	0.13	6.7	89.33	11.91	7.21	96.13	12.82	6.82	90.93	12.12
EC (µs/cm)	2000	0.00	161.33	8.07	0.00	489.66	24.48	0.01	429.33	21.47	0.01
TSS (mg/L)	600	0.00	7.01	1.17	0.00	675	112.50	0.19	365	60.83	0.10
COD (mg/L)	200	0.01	3.99	2.00	0.01	890	445.00	2.23	949	474.50	2.37
BOD_5 (mg/L)	80	0.01	82.3	102.88	1.29	584	730.00	9.13	663	828.75	10.36
NH_4 (mg/L)	150	0.01	0.77	0.51	0.00	147.1	98.07	0.65	133.4	88.93	0.59
PO_4	50	0.02	16.5	33.00	0.66	78.18	156.36	3.13	164.1	328.20	6.56
TOTAL		0.16			15.83			27.59			28.11
overall WWQI					**99.13**			**172.81**			**176.03**

S_i = Standard permitted Limit; W_i= the unit weight of the parameter; C_i=Value of the sample, Qi=Sub index of the parameter

Table 4: Heavy Metal Pollution Index (HPI) value of the different samples.

				Control Water			Prison's Wastewater			Hospital's wastewater		
Heavy Metal	S_i	I_i	W_i	M_i	W_i*Q_i	HPI	M_i	W_i*Q_i	HPI	M_i	W_i*Q_i	HPI
Copper (µg.L^{-1})	2000	200	0,0005	9.61	0.005	0.044	41.03	0.004	0.037	93.16	0.003	0.025
Zinc (µg.L^{-1})	5000	2000	0,0002	0.65	0.013	0.110	19.66	0.013	0.109	37.18	0.013	0.108
Cadmium (µg.L^{-1})	10	3	0,1000	0.06	4.200	34.739	3.90	1.286	10.635	4.71	2.443	20.206
Lead (µg.L^{-1})	50	10	0,0200	2.79	0.361	2.982	426.67	20.834	172.320	253.75	12.188	100.806
Fe (µg.L^{-1})	5000	300	0,0002	801.17	0.002	0.018	389.35	0.0004	0.003	522.62	0.001	0.008
HPI total						**37.893**			**183.100**			**121.145**

S_i = Standard permitted Limit of the heavy metal; I_i =Ideal Value; W_i= the unit weight of the of heavy metal; Qi=Sub index of the parameter, M_i= Monitored value of heavy metal ; HPI=Heavy Metal Pollution Index

4. CONCLUSION

The main purpose of this study was on the one hand to characterize wastewater from spaces with high human concentration such as prisons and hospitals and on the other hand to assess the potential impact of this wastewater on the environment. It appears from the analysis of the physicochemical parameters of wastewater that only temperature and pH are in the WHO's norm. Thus, the wastewater of the central prison and the regional hospital is characterized by high loads of almost all the pollutants studied. This can be explained by the overcrowding in the prison and also by the intense activity of the care produced by the regional hospital. The non-standard values of COD, BOD_5 and heavy metals suggest the potential for pollution in the soil if this water is discharged without prior treatment into the surrounding nature. It would therefore be urgent to install treatment plants for these effluents before their discharge into the natural environment as recommended by the Cameroonian legislator for all wastewater heavily loaded with pollutants.

REFERENCES

1. Pier GN (2013) Eau, assainissement, hygiène et habitat dans les Prisons.
2. Anonyme (2013) Plan Communal de Développement de Ngaoundéré 1er : Ministère de L'Administration Territorial et de la Décentralisation, République du Cameroun, Région de l'Adamaoua
3. Sharma P, Mathur N, Singh A, Bhatnagar P (2019) Physico-Chemical Assessment of Hospital Wastewater Quality. Int J Dev Res 4:1915–1918
4. Darsy C, Lescure I, Payot V, Rouland G (2002) Effluents des établissements hospitaliers : teneur en microorganismes pathogènes, risques sanitaires, procédures particulières d'épuration et de gestion des boues. Off Int l'Eau Serv Natl d'Information Doc sur l'Eau 10 p
5. Verlicchi P, Galletti A, Petrovic M, BarcelÓ D (2010) Hospital effluents as a source of emerging pollutants: An overview of micropollutants and sustainable treatment options. J Hydrol 389:416–428. https://doi.org/10.1016/j.jhydrol.2010.06.005
6. Gautam AK, Kumar S, Sabumon PC (2007) Preliminary study of physico-chemical treatment options for hospital wastewater. J Environ Manage 83:298–306. https://doi.org/10.1016/j.jenvman.2006.03.009
7. Rodier J (2009) Jean Rodier - L'analyse de l'eau. Int. J. Biol. Chem. Sci. 1:1579
8. Wu D (2022) A Review of Detection Techniques for Chemical Oxygen Demand in Wastewater. https://doi.org/10.3844/ajbbsp.2022.23.32
9. Khudhair BH, Makki A, Jbbar RK (2018) AL-DIWANIYAH SEWAGE TREATMENT PLANT BASED ON WASTEWATER QUALITY
10. Jamshidzadeh Z, Barzi MT (2019) Wastewater quality index (WWQI) as an assessment tool of treated wastewater quality for agriculture : a case of North Wastewater Treatment Plant effluent of Isfahan. 1965:
11. Ayoub M, El-morsy A (2021) Applying the Wastewater Quality Index for Assessing the Effluent Quality of Recently Upgraded Meet Abo El-koum Wastewater Treatment Plant. 22:128–133
12. Ugbebor JN, Ntesat UB, Harcourt P (2022) Effects of Septic Tank Proximity to Boreholes on groundwater contamination at Igwuruta , Rivers State , Nigeria. 10–17. https://doi.org/10.9790/1813-1104011017
13. Yadav A, Shukla DN (2015) Assessment of Heavy metal Accumulation in Wastewater flooded soil of Allahabad , Uttar Pradesh , India. 2:324–329
14. Majhi A, Biswal SK (2016) Application of HPI (Heavy Metal Pollution Index) and Correlation Coefficient For The Assessment Of Ground Water Quality Near Ash Ponds Of Thermal Power Plants. 395–405
15. Jazza SH, Najim SS, Adnan MA (2021) Using Heavy Metals Pollution Index (HPI) for assessment quality of drinking water in Maysan Province in Southern East in Iraq. Egypt J Chem 65:703–709. https://doi.org/10.21608/ejchem.2021.89658.4295
16. Mthembu PP, Anderson WP (2021)

Integration of Heavy Metal Pollution Indices and Health Risk Assessment of Groundwater in Semi- arid Coastal Aquifers , South Africa

17. Bigdeli M, Seilsepour M (2008) Investigation of Metals Accumulation in Some Vegetables Irrigated with Waste Water in Shahre Rey-Iran and Toxicological Implications. Am J Agric Environ Sci 4:86–92

18. Aguiza AE, Ombolo A, Ngassoum MB, Mbawala A (2014) Suivi de la qualité physico-chimique et bactériologique des eaux des cours d'eau de Ngaoundéré, au Cameroun. Afrique Sci Rev Int des Sci Technol 10:135–145

19. Mbog SM (2013) Evaluation de la gestion des déchets liquides hospitaliers : cas des eaux usées du Centre Hospitalier Universitaire (CHU) de Yaoundé. Université de Yaoundé I

20. Compaoré (2013) Gestion des eaux usées et excretas dans un milieu carcéral en Afrique de l'ouest: cas de la maison d'arrêt et de correction de Ouagadougou (Maco) au Burkina Faso). Eur J Sci Res 34:280–289

21. De Villers J, Squilbin M, Yourassowsky C (2005) Les données de l'IBGE : "L'eau à Bruxelles." 16

22. Nkambara C (2020) Impact Of Ngaoundéré Central Prison And Regional Hospital Waste Water On The Quality Of Water Used In Agriculture Around This Area in Ngaoundéré - Cameroon. (Ngaoundéré Central Prisons). The University of Ngaoundéré

23. Mara DD, Cairncross S (1991) Appréhension des risques sanitaires liés à la réutilisation des eaux résiduaires et des excrétas en agriculture et aquaculture. Genève

24. Heriarivony SC, Razanamparany B, Rakotomallala J (2015) Caracteres physico-chimiques et bactériologiques de l'eau de consommation (puits) de la communce rurale d'Antanifotsy, Région Vakinakaratra, Madagascar. Larhyss J 7–17

25. AFNOR (1999) La qualité de l'eau. Tome 1. Terminologie. Echantillonnage. Contrôle qualité. 493

26. Baaissa FZ, Redjouh S (2019) Charge métallique dans les eaux usées de chaâbet Roba. Université Mohamed Khider de Biskra

27. Degremont G (1990) Mémento technique de l'eau. Tome 1.

28. Zeghoud MS (2013) Etude d'un système d'épuration des eaux usées urbaines par lagunage naturel de village de Méghibra. Université El-Oued, Algérie

29. Celerier J-L, Faby J-A, Loiseau G, Juery C (2002) La dégradation de la qualité de l'eau potable dans les réseaux

30. Fathallah Z, Ellkharrim K, Fathallah R, et al (2014) Etude physicho-chimique des eaux usées de l'unité industrielle papetière (CDM) à Sidi Yahia el Gharb (Maroc). Larhyss J 20:57–69

31. Idrissi YA, Alemad A, Aboubakar S, et al (2015) Caractérisation physico-chimiques des eaux usées de la ville d'Azilal -Maroc-. Int J Innov Appl Stud 11:556–566

32. Evens E, Perrodin Y, Keck G, et al (2005) Ecotoxological risk assessment of hospital wastewate: a proposed framework for raw effluents discharging into urban sewer network. J Hazard Mater 117:1–11

33. OMS (2012) Utilisation des eaux usées en agriculture. In : L'utilisation sans risque des eaux usées, des excréta et des eaux ménagères

34. Chiffoleau JF, Auger D, Chartier E (1999) Fluxes of selected trace metals from the Seine estuary to the eastern Englisch Channel during the period of August 1994 to July 1995. Cont Shelf Res 19:2063–2082

35. Adjia R (2002) Paramètres physico-chimiques indicateurs de pollution des eaux et des sols des zones périurbaine et urbaine de Ngaoundéré. ENSAI Univ de Ngaoundéré