



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

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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, BOD₅; 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 (wwqi); 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. MATERIALS AND METHODS

2.1 Study Area and Sampling Sites

Fig. 1 shows the geographic location of the study area and the three main water sampling sites. Wastewaters from the central prison and the

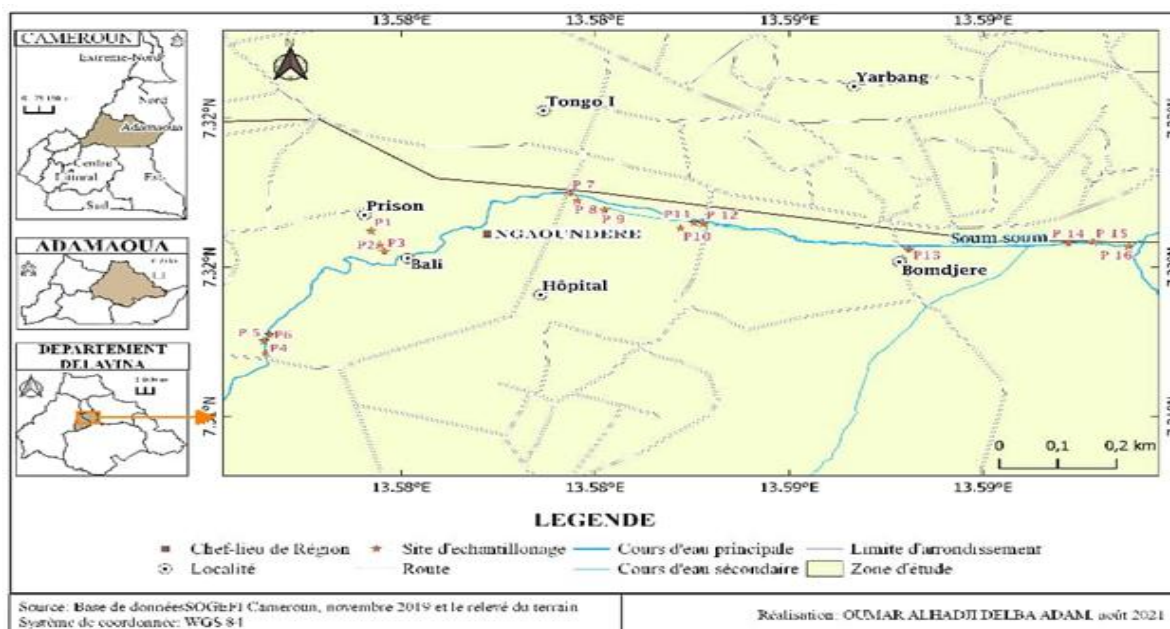


Fig. 1. Geographical location of sampling sites

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.

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. BOD₅ was determined using an Oxytop which heads to measure the differences in partial pressure of O₂ et CO₂. 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 Spectral 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 calculated 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 physico-chemical parameters studied. The water temperature in the different sampling points varied between 22.9 ± 0.0 and $23.5 \pm 0.1^\circ\text{C}$ 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.

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 $489.66 \pm 319.20 \mu\text{s/cm}$. There was no significant difference in electrical conductivity between the different sites ($F=1.73$; $P=0.254 > 0.01$). The Total suspended solids (TSS) studied varied between 7.01 ± 0.11 and $675.67 \pm 2.87 \text{ mg/L}$. Water of the control zone have a concentration of $7.01 \pm 0.11 \text{ mg}$ of TSS/L, the wastewater of the Prison and the Hospital have respectively $675.67 \pm 2.87 \text{ mg}$ of TSS/L and $365.74 \pm 6.15 \text{ mg}$ 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 Aguiza, et al. [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 ($22.9 \pm 0.0^\circ\text{C}$) lower than the $28.28 \pm 1.8^\circ\text{C}$ found by Mbog [19] on the wastewater of the Yaoundé University Hospital. The temperature at the prison level ($23.13 \pm 0.05^\circ\text{C}$) 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 ($6.5 < \text{pH} < 8.5$). These results corroborate those obtained by Aguiza, et al. [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 Mbog [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 $161.33 \mu\text{S/cm}$ for the waters of the control zone. This value is between 100 and $200 \mu\text{S/cm}$, which reflects a low mineralization and therefore a low amount of dissolved salts. Waters with a conductivity of less than $200 \mu\text{S/cm}$, 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 $333 \mu\text{S/cm}$ and $666 \mu\text{S/cm}$ 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 ($489.66 \mu\text{S/cm}$) are higher than the $181.85 \mu\text{S/cm}$ of the Annex Building and lower than the $525.53 \mu\text{S/cm}$ of the Grand Building obtained by [20] at the Ouagadougou Prison (*Maco*) in Burkina Faso. The values obtained at the hospital wastewater ($429.33 \mu\text{S/cm}$) are higher than the $340.2 \pm 210.2 \mu\text{S/cm}$ 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 ($\text{dS/m} < 3$) 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 ($\leq 30 \text{ mg TSS/L}$) for wastewater discharges. The content obtained of $949.72 \pm 6.38 \text{ mg of TSS/L}$ at the hospital level is higher than the $111.7 \pm 67.3 \text{ mg of TSS/L}$ obtained by [19] at the wastewater level of the university hospital in Yaoundé. The value of $890.78 \pm 11.34 \text{ mg of TSS/L}$ 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 ($100\text{-}350 \text{ mg/L}$) 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 $2.93 \pm 3.15 \text{ NTU}$ ($\text{NTU} < 5$), 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 ($28.80 \pm 19.84 \text{ NTU}$) is between $5 < \text{NTU} < 30$. The turbidity at the level of the Prison Waters ($139.62 \pm 131.16 \text{ NTU}$), is highly high ($\text{NTU} > 50$), 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 BOD₅ make it possible to determine the impact of an effluent on the receiving environment. [22] also has elevated BOD₅ values in these waters. According to the results obtained from the BOD₅ content, the value obtained from the waters in the BOD₅ 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 O₂ per liter characteristic of good quality water (WHO, 2012). The Prison's BOD₅ value (584.75±62.49 mg/L) is lower than the total BOD₅ 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 BOD₅ 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 O₂/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 O₂/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. The Chemical Oxygen Demand (COD) content obtained in the different waters varied between 3.99±0.33 and 949.72 mg O₂/L. the average COD content obtained at the level of the waters of the control zone is 3.99±0.33 mg O₂/L, at the level of the Prison this COD content is 890.78±11.34 mg O₂/L and finally at the hospital level 949.72±6.38 mg O₂/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 (BOD₅) values obtained in the different sampling points ranged between 2.35±0.61 and 2063.78±155.03 mg O₂/L. In the control area, the BOD₅ concentration is 2.35±0.61 mg O₂/L, while wastewater from the Prison and the Hospital had BOD₅ concentration of 584.75±62.49 mg O₂/L and 6 63.78±55.03 mg O₂/L respectively. There was a significant difference between the different sampling sites ($F=14889$; $P=0.000<0.01$).

The COD/BOD₅ 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/BOD₅ 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/BOD₅ ratio ($F=144$; $P=0.000<0.01$) and TSS/BOD₅ ($F=311$; $P=0.000<0.01$) 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/BOD₅ and TSS/BOD₅ 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/BOD₅ ratio is important for the definition of the effluent treatment chain. Indeed, a low value of the COD/BOD₅ 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/BOD₅ ratio makes it possible to deduce whether the wastewater discharged directly into the receiving

environment is of domestic origin. The mean COD/BOD₅ 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/BOD₅<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 COD/BOD₅ of 0.71±0.0 and 0.41±0.02 respectively. The organic load is marked by very high values of BOD₅, 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 2 presents the concentration of different heavy metals present in the study area.

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 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±0,57 ^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±0,16 ^b	1.43±1.26 ^a	-	*
TSS/BOD ₅	2.98±0.12 ^c	1.15±0,01 ^b	0.55±0.02 ^a	-	*

Cam=Cameroon; TSS=Total Suspended Solids; COD=Chemical oxygen demand; BOD₅=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

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%

Table 3. Wastewater quality index (wwqi) values of the different samples

Parameters	Control Water					Prison's Wastewater				Hospital's wastewater		
	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, Q_i=Sub index of the parameter

Table 4. Heavy metal pollution index (HPI) value of the different samples

Heavy Metal	Control Water						Prison's Wastewater			Hospital's wastewater		
	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; Q_i=Sub index of the parameter, M_i= Monitored value of heavy metal; HPI=Heavy Metal Pollution Index

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].

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, BOD₅ 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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