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Physico-chemical quality and toxicity of wastewater from Katiola commune (North-Central Côte d'Ivoire)

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Abstract

In Africa in general and in Côte d'Ivoire in particular, the management of wastewater in the context of sanitation is devolved to cities and municipalities. Katiola commune is no exception. In fact, this municipality faces problems with wastewater management. The objective of this study is to evaluate the physicochemical quality and toxicity of wastewater from this municipality with a view to implementing an appropriate management method. Thus, surveys followed by field visits and wastewater sampling were carried out on six (06) sites. The data from the analyzes were compared to the guide values of the WHO, France and Ivory Coast. The results reveal that populations dispose of wastewater using unconventional practices (90%). This wastewater is considerably mineralized (469 and 663 µS/cm), of domestic origin and easily biodegradable (biodegradability index equal to 2.49) with a normal pH. In terms of toxicology, Katiola wastewater is rich in lead (26.9 to 640 µg/L) and nickel (50 to 779.2 µg/L). As for pesticides, beta-endosulfan and endrin have concentrations lower than the limit value set by the French standard, thus meaning a low impact on humans and their environment.

Keywords: Wastewater; Physico-chemical quality; Toxicity; Katiola; Côte d'Ivoire

1. Introduction

Wastewater management offers an opportunity in a world where water resources are limited **[1]**. However, the treatment of this wastewater before its release into nature represents a major difficulty for many countries around the world. This difficulty is more accentuated in underdeveloped countries which lack resources. According to **[1]**, developed countries treat around 70% of the municipal and industrial waste water they produce compared to only 8% in poor countries.

In Africa, the situation of wastewater disposal and treatment is alarming. Most of the wastewater evacuation networks connected to mechanized treatment plants set up after independence are today non-functional and the raw wastewater produced is evacuated to the lowlands [2, 3]. However, many studies highlight the negative consequences of poor sanitation, in terms of health, environment and economics. According to these authors 51% of African countries experience severe environmental pollution which risks harming water resources.

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Ivorian cities, like those in Africa, are constantly polluted by waste from households, commercial, artisanal and industrial activities [4]. The insufficiency of sanitation networks and the non-connection of the majority of the population to the sewer mean that we observe discharges of wastewater without treatment into natural environments [5].

Katiola town, located in the north-central part of the country, is no exception to this situation. It is therefore with this in mind that the present study set itself the objective of evaluating the physicochemical quality and toxicity of wastewater from this municipality with a view to establishing an appropriate management method.

2. Material and methods

2.1. Study area

Katiola commune is located in the center – north of Côte d'Ivoire and covers an area of 1092 Km^2 (figure 1). Katiola town, capital of the Hambol region, is approximately four hundred and thirty (430) kilometers from Abidjan (economic capital) between 8o 00' and 9o 20' North Latitude, 4o 43' and 5o 78' Longitude West and an altitude of 320 meters [6]. It has many small rivers, backwaters and lowlands serving as valleys and small lakes. The latter constitute the place where wastewater is discharged by populations (90,641 inhabitants according to the 2021 general population census).

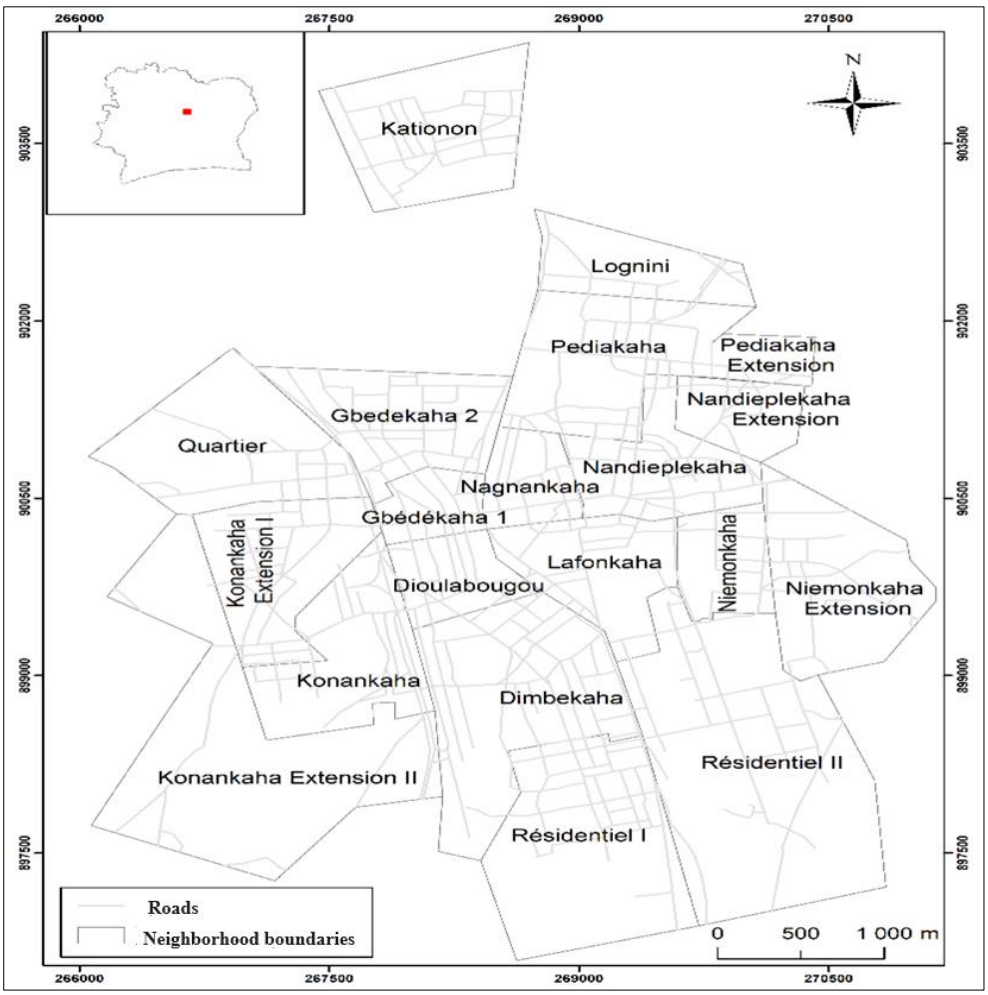

Figure 1 Map Katiola commune

2.2. Diagnosis of the wastewater management method

To understand the household wastewater management system, a questionnaire survey was conducted from April 22 to May 19, 2022. This survey also aimed to identify household wastewater disposal methods and their perceptions of the wastewater management in their immediate living environments. The 2021 general population census shows that the

commune of Katiola has 18,052 households. The sampling technique adopted is that of Shawartz **[7],** with a representative sample size of 400 households distributed equitably across the city's 20 neighborhoods.

2.3. Physico-chemical and toxic quality of wastewater

A prospecting visit made it possible to take stock of the situation and choose six (06) wastewater sampling points numbered from P1 to P6 (table 1).

Table 1 Sampling sites and points

Sites and Neighborhoods	Sampling Points
Dioulabougou 1	P1
Dioulabougou 2	P2
Dioulabougou 3	P3
Dabakala station	P4
Market	P5
City hall	P6

2.3.1. Collection and storage of samples

The samples were taken using a one liter handle cup. The 0,5 liter bottles intended to contain the waste water were rinsed with the water to be analyzed and labeled using adhesive tape. The vials were filled to reflux and closed tightly to avoid air bubbles. The samples are stored in a cooler and sent to the laboratory for analysis.

The parameters measured in the laboratory are : sulfate (SO_4^{2-}), ammonium ($NH4^+$), chemical oxygen demand (COD), five-day biological oxygen demand (BOD5), heavy metals such as nickel (Ni) and lead (Pb) as well as the pesticide. Parameters such as temperature, pH and conductivity were measured in situ at each wastewater point sampled.

2.3.2. Parameter analysis methodology

For parameters measured in situ, the previously calibrated measuring device (the multiparameter) is powered on a few minutes before handling. The probes are then immersed in the water samples taken and selection of the desired parameter function gives the value of the latter on the display screen. For the parameters measured in the laboratory, the analysis methods are summarized in Tables 2 and 3

Table 2 Method for analyzing chemical parameters and heavy metals

Parameters	Material	Methods used
Sulfate	Spectrometer	Sulfaver 4 colorimetric method
Ammonium	Spectrometer	Colorimetric salycilate dosage
DBO5	Oximeter	Oximeter method
DCO	Titrator	Titration method
Plomb	Atomic absorption spectrometer	Dosage according to wavelength
Nickel	Atomic absorption spectrometer	Dosage according to wavelength
Pesticide	Chromatograph	Pesticide dosage in water

Table 3 Biodegradability index

DCO/DBO5 Ratio
DCO/DBO < 2 Easily biodegradable
2 < DCO/DBO > 4 Moderately biodegradable
DCO/DBO5 > 4 Hardly biodegradable

2.3.3. Data processing method

The Google Earth software combined with the ground plan of Katiola town made it possible to direct our questionnaires and our visits. Thus, a questionnaire was submitted to the different heads of households. This questionnaire was compiled using Sphynx software. Subsequently, the statistical data obtained were exported to the Microsoft Excel 2016 spreadsheet. This spreadsheet allowed the creation of the graphs. Global Positioning System (GPS) coordinates collected in the field were projected onto the DEM in ArcGIS10 3 mapping software.

3. Results

3.1. Wastewater management method in Katiola commune

The management of sewage, dishwater and laundry is problematic. The drainage network intended to ensure the transport of rainwater in Katiola town is insufficient and clogged by solid waste. Only asphalt roads are equipped with drainage channels for water from the roadway. There is practically no wastewater collection and disposal infrastructure. Households use various methods of disposing of domestic wastewater (washing water, bath water, dishwashing water, cooking water, etc.) (figure 2). Non-conventional forms of evacuation are predominant (90% including 81% in the streets and 9% in gutters). The recommended route, which is the use of pits, only represents 10% of practices. Indeed, the septic tank is a device intended to receive all the wastewater from the house.

Figure 2 Wastewater management method by populations

3.2. Physico-chemical and toxicological quality of wastewater

3.2.1. Analysis of physico-chemical parameters

Physicochemical parameters of wastewater are characterized by their minimum and maximum values, their averages as well as their standard deviations (Table 4).

Table 4 Physico-chemical characteristics of wastewater

Parameters	Minimum	Maximum	Average	Standard deviation	Standards
pH	6,8	9,95	7,55	1,08	5,5 – 8,5 (Côte d'Ivoire)
CE (µS/cm)	149	663	460,66	164,23	< 400 (WHO)
NH4+ (mg/L)	0,1	7,7	3,4	2,91	< 2 (WHO)
$SO4^{2}$- (mg/L)	2	50	17,83	16,93	< 600 (Maroc)
DCO (mg/L)	43 ,78	282	131,58	83,27	250 - 500 (WHO)
DBO5 (mg/L)	17	113,04	52,74	265,84	100 - 150 (WHO)

Table 4 shows a pH variation from 6.8 to 9.95 across the sampling sites with a mean of 7.55 and a standard deviation of 1.08. Its average complies with Ivorian wastewater discharge standards (5.5 to 8.5).

The electrical conductivity (EC) of wastewater from different sampling sites varies between 149 and 663 (µS/cm) with an average of 460.66 (µS/cm). The average value of electrical conductivity is higher than the rejection standard set by the WHO which is 400(µS/cm) then the value of the standard deviation of electrical conductivity is 164.23 (µS/cm). It appears from this analysis that the EC load of these waters does not comply with the WHO guideline values.

Sulfate concentrations in wastewater from the sites vary between 2 and 50 mg/L, with a mean value of 17.83 mg/L and a standard deviation of 16.93. The discharge limit value is 600 mg/L according to the Moroccan standard. Taking this standard into account, we can say that the wastewater from Katiola commune has a low sulfate concentration. Ammonium varies between 0.1 and 7.7 (mg/L) with an average of 3.4 mg/L and a standard deviation of 2.91 as well as a release limit value of 2 mg/L. This means that the wastewater from these sampling points does not meet WHO discharge standards.

The chemical oxygen demand (COD) of the different sampling points varies greatly between 43.78 and 282 mg/L with an average value of 131.58 mg/L, a WHO rejection standard of between 250 and 500 mg/L. These values show that all COD concentrations less than or equal to 250 mg/L are of good quality and all concentrations between 250 and 500 mg/L are of acceptable quality. However, all COD concentrations above 500 mg/L are of poor quality. In the case of this study, all COD values meet the standard. The biological oxygen demand (BOD5) varies between 17.55 and 113.04 mg/L with an average value of 52.74 mg/L then a rejection standard of between 100 and 150 mg/L set by the WHO. These values show that all BOD5 concentrations less than or equal to 100 mg/L are of good quality for the discharge standard and any concentration between 100 and 150 mg/L are of acceptable quality. However, all BOD5 concentrations above 150 mg/L are of poor quality. Therefore, Katiola wastewater meets WHO discharge standards. The average COD/BOD5 ratio gives a value of 2,49. This value reflects the biodegradability of wastewater loaded with organic matter.

3.2.2. Analysis of wastewater toxicity parameters

The toxicity parameters found in the wastewater of Katiola commune consist of pesticide (Beta-endosulfan and Endrin) and heavy metals (nickel and lead). The characterization of the toxic parameters, recorded in Table 5, highlights the minimum and maximum values, the means and the standard deviations.

Table 5 Characterization of wastewater toxicity parameters

Parameters	Minimum	Maximum	Average	Standard deviation	Standards (OMS/France)
Pesticides (µg/L)	0,11	0 ,34	0,08	0,10	< 25
Lead (µg/L)	26.90	640,30	228,40	236,55	< 1
Nickel (µg/L)	290	779,29	461,83	161,92	< 3

When we compare the results of the analyzes to the standards (WHO/French), we notice that these parameters have values well above the standards with the exception of the pesticide. Two pesticides, Beta-endosulfan and Endrin, were detected respectively at points P3 and P4 with low levels (on average 0.08 µg/L). These levels therefore comply with the 2018 French discharge standards which are 25 µg/L.

Figure 3 shows us a graph which reflects the presence of nickel on all the sampling sites. However, the value of nickel varies from one site to another from 50 to 779.29 µg/L with an average value of 461.83 µg/L then a standard deviation of 161.92. This figure also shows that nickel wastewater discharges do not comply with French standards which are less than 3 µg/L.

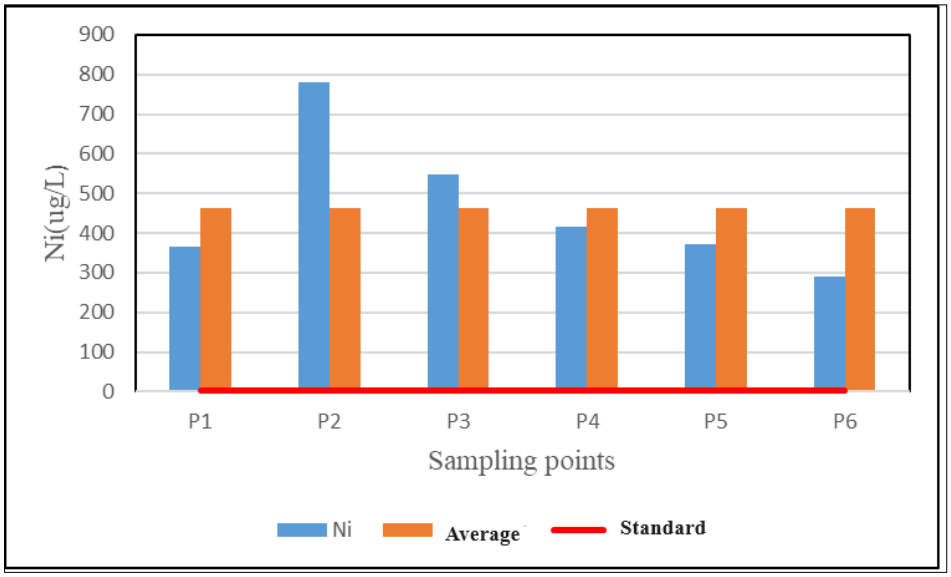

Figure 3 Variation of nickel in wastewater from sampling sites

Figure 4 shows the presence of lead in wastewater from the different sampling sites. The concentration of lead in this wastewater varies between 26.9 and 640 µg/L with an average value of 228.4 µg/L then a standard deviation of 236.55. The limit value for the release of lead into the environment is 1 µg/L according to the French standard. In view of this standard, we note that lead discharges do not comply with the standard.

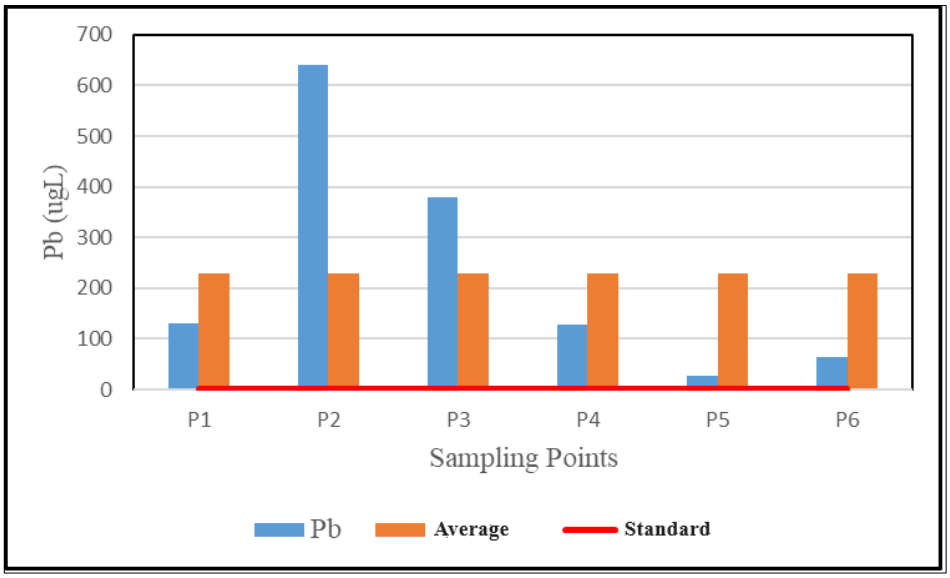

Figure 4 Variation in wastewater lead from sampling sites

4. Discussion

This study aims to diagnose wastewater management, characterize the physicochemical quality and toxicity of wastewater from the municipality of Katiola. It reveals that regarding the method of wastewater disposal, 81% is dumped in the street and 9% in the gutters, thus showing a predominance of unconventional practices. Only 10% of this water is discharged into the pits. The profile of Katiola town in terms of wastewater management is the same as many towns in the country. This is the case of the town of Gagnoa where, according to [8], gutters (32.17%) and streets (30.33%) are used a lot by households to dispose of their wastewater. And some even get rid of them behind open-air houses (13.50%) and in the Guéri River (1.67%). This management method is the same as certain large cities in Africa such as Dakar. Indeed, the Senegalese capital, due to its galloping demographics, rejects large quantities of wastewater, the management of which poses problems [9, 10].

The physicochemical analysis of Katiola wastewater presents pH values which vary from 6.8 to 9.95. These values comply with Ivorian and WHO discharge standards. However, the market point at a higher pH (9.5) therefore beyond the standard. This could be explained by the use of cleaning products by the surrounding population.

The electrical conductivity varies between 149 and 663 µS/cm. Only the two points on the market meet WHO standards (400 µs/cm). Which implies that the wastewater from the Dioulabougou district and the station presents a high mineralization. This would be due to a massive contribution of detergents brought by domestic wastewater.

The BOD5 values measured (17.55 - 113.04 mg/L) show low pollution of this wastewater in organic matter [11, 12] obtained BOD5 values greater than 220.08 mg/L in the Abidjan district. For COD, the values observed are between 43.78 mg/L and 282 mg/L. These wastewater discharges comply with the WHO standard (500 mg/L). These effluents have less suspended matter. The COD/BOD5 ratio gives an indication of the biodegradability of wastewater. The value (2.49 mg/L) obtained in this study confirms the biodegradability and the origin of this wastewater. With this biodegradability coefficient obtained, the origin can only be purely domestic. This ratio is similar to that (2.42) obtained by [13] for raw wastewater from five towns in the Chaouia region (Maroc).

Regarding sulfate (SO_4^{2-}), the values observed are between 2 and 50 mg/L. They are in compliance with the Moroccan standard (2013) which has a limit value of 600 mg/L. The sulfate values observed indicate a low concentration in the sampled environments. For the ammonium ion ($NH4^+$), the values vary between 0.1 mg/L and 7.7 mg/L. The values obtained at the Dioulabougou and station sites (5.4; 5.5; 7.7 mg/L) are beyond the WHO standard (2 mg/L). The high ammonium content in this wastewater could be explained by the activity of organic decomposition and discharge of excreta.

For lead, the values observed (26.9 - 640 µg/L) are well above the 2010 French standard which sets the discharge limit value at 1 µg/L. The high concentration of lead in this wastewater can be explained by anthropogenic factors such as the incineration of domestic waste and automobile gasoline [14]. Likewise, the nickel values recorded (50 – 779.29 µg/L) are well above the French standard (3 µg/L). These values accentuate the toxic nature of this wastewater. In terms of pesticides, the majority of sites sampled do not show any sign of presence except sites P3 and P4 which have the beta-endosulfan (0.12 µg/L) and endrin (0.34 µg/L) forms. However, the wastewater sampled complies with French discharge standards (25 µg/L). However, it is important to remember that whatever the concentration, pesticides remain toxic. Indeed, endosulfan (EDS), like most other pesticides, can cause acute toxicity in animals and humans. Symptoms of poisoning include irritation of the stomach and small intestine, congestion of the kidneys, lungs and adrenal glands, atony, nausea, vomiting, convulsions and dizziness [15, 16].

5. Conclusion

The study carried out on wastewater from the municipality of Katiola allowed us to diagnose the management of wastewater and then to characterize the physico-chemical quality as well as the toxicity of this wastewater. With regard to wastewater management, it is clear that the wastewater drainage networks are insufficient. In addition, septic tanks are absent or poorly sized. Given the insufficiency of these canals which are often blocked by solid waste and wastewater management systems, the population opts for an autonomous wastewater management system, unconventional practices (more than 90%). It appears from the study that the pH values obtained mostly respect the Ivorian discharge standard. These waters are considerably mineralized with a significant conductivity of between 469 and 663 µS/cm. The wastewater that was the subject of the study is all easily biodegradable and of domestic origin with a biodegradability index equal to 2.49. Regarding the toxicological characterization of Katiola wastewater, it should be noted that this water is excessively rich in lead and nickel with values of 26.9 to 640 µg/L and 50 to 779.2 µg/L

respectively. L. As for pesticides (beta-endosulfan and endrin), their concentrations in the environment are lower than the limit value set by the French standard, thus signifying a low impact on humans and their environment.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there are no conflicts of interest that is relevant to the content of this article.

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