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Study of the physico-chemical and metallic characteristics of urban wastewater discharged without treatment into the Ouladine lagoon in Grand-Bassam, Ivory Coast

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ABSTRACT: The city of Grand-Bassam in the south-east of Côte d'Ivoire is faced with a sanitation problem, the direct consequence of which is the untreated discharge of wastewater into the Ouladine lagoon. This work aims to determine the physico-chemical and metallic quality of urban wastewater discharged into the Ouladine lagoon without treatment. The samples were taken respectively during the dry season (March 2021) and the rainy season (June 2021) on seven (07) outlets of the pipes. The pH, temperature, and dissolved oxygen (O2) were measured in situ using a multi-parameter HANNA HI 9829. Parameters such as Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS) were measured in the field with a portable multi-parameter spectrophotometer Pastel UV - Secomam. The various physico-chemical and metallic parameters were analysed in the laboratory according to the analysis methods recommended by the French normalisation association (Association Française de Normalisation). The results obtained show that the parameters studied (T, pH, DO, COD, TSS, TKN, Pt, As, Cd and Pb) have variable contents from one site to another. Most of the parameters exceeded the limit values recommended by Ivorian regulations for wastewater, except for the levels of metals, which remained low at all sampling points. According to the results of this study, a municipal wastewater treatment system must be set up to discharge a liquid effluent that complies with Ivorian regulatory requirements.

KEYWORDS: Wastewater, pollution, physico-chemistry, metals, Grand-Bassam, Ivory Coast.

1. INTRODUCTION

Population growth accompanied by rapid urbanization, intensive water use, and lack of wastewater treatment are causing numerous disturbances to the natural environment. Pollution from wastewater discharge in coastal areas poses a threat to public health, wildlife, and sources of income such as fishing and tourism [1]. These wastewaters often contain a wide range of contaminants that significantly alter the physico-chemical properties of the receiving environments [2]. There is a direct proportionality between increasing urbanization and the rate of water pollution [3]. The use of physico-chemical characterization parameters of urban effluents is a good way to estimate the quality of these urban discharges and their impact on the receiving environment [4]. Water pollution has become a global concern, but most developing countries are still unaware of the seriousness of this problem and continue to produce huge and increasing amounts of pollutants [5]. In the coastal town of Grand-Bassam, as in many other secondary towns in Côte d'Ivoire, the issue of wastewater management remains one of the main environmental problems, due to insufficient sanitation infrastructure and a lack of treatment systems. This absence leads to the discharge of wastewater without prior treatment into the receiving environment, which is the Ouladine lagoon, thus causing a risk of degradation of this water. In this context, data on the quality of these effluents about all priority substances is essential. This work aims to determine the physico-chemical and metallic quality of urban wastewater from the town of Grand-Bassam discharged into the Ouladine lagoon without treatment. This characterization of urban wastewater is a good indicator of the quality of discharges and their impact on the receiving environment.

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2. MATERIAL AND METHODS

2.1. PRESENTATION OF THE STUDY AREA

The town of Grand-Bassam is in the south-east of Côte d'Ivoire between 5°11 and 5°18 north latitude and 3°52 and 3°38 west longitude. Grand-Bassam is a historic town and was the first capital of Côte d'Ivoire from 1893 to 1900 during the colonial period. The opening onto the Atlantic Ocean and the proximity of the city of Abidjan make fishing, crafts, and tourism the main economic activities of the city. The study area is subject to a transitional equatorial climate or Atean climate with four alternating rainy and dry seasons.

2.2. LOCATION OF SAMPLING POINTS

Within the framework of this study, the identification of sampling sites consisted of identifying the various wastewater discharge points in the town of Grand Bassam. The choice of stations was made in such a way as to obtain good spatial coverage and considered the large pipes draining enough wastewater to be discharged directly into the Ouladine lagoon (fig.1).

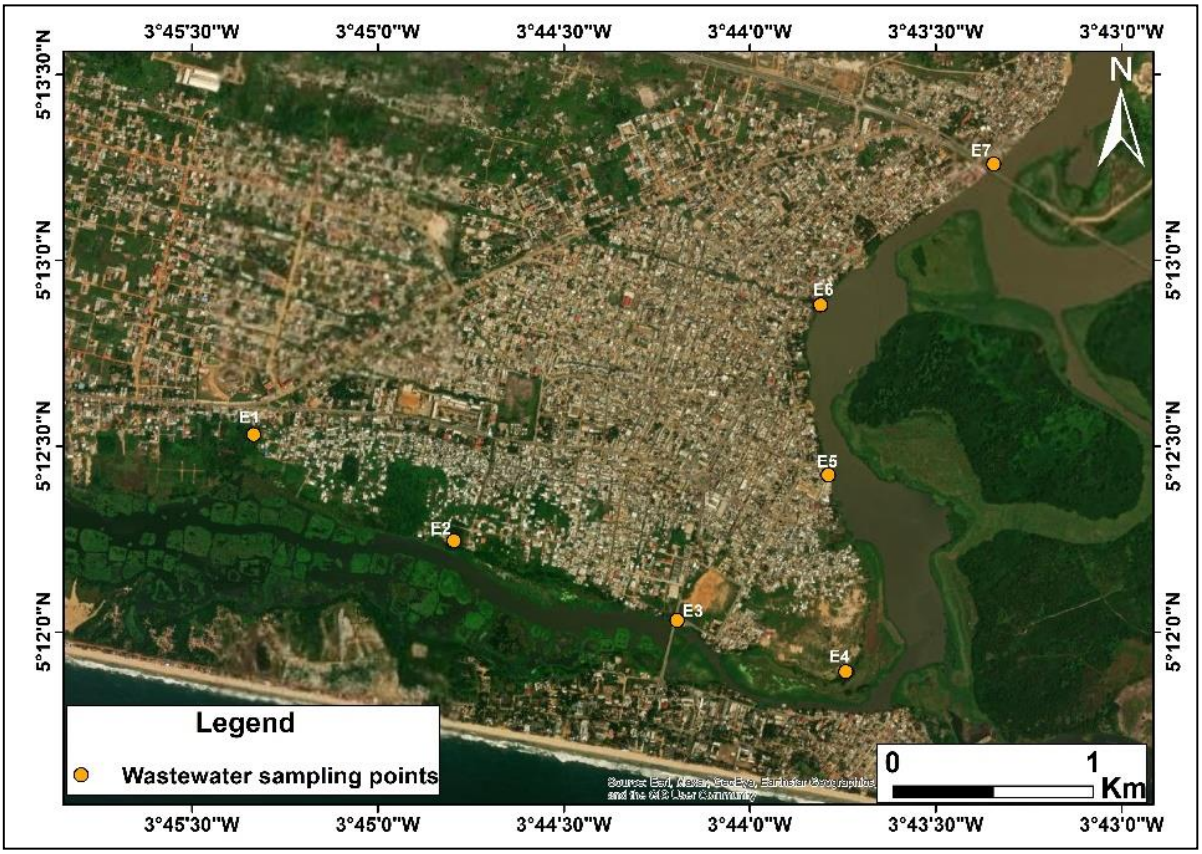

Fig. 1. Sampling sites

2.3. SAMPLING

The samples were taken during the dry season (March 2021) and the rainy season (June 2021) respectively at seven (07) pipe outlets. Two (02) water samples were taken at each station during both seasons. The water samples were collected in one (01) litter polyethylene bottle, rinsed 3 times with the water to be sampled. All bottles were filled to the brim and sealed, then stored in a cooler to maintain the temperature at 4°C and transported to the analysis laboratory.

2.4. METHODS OF ANALYSIS

Measurements of certain parameters were carried out in situ using a multi-parameter HANNA HI 9828. These are Temperature (T), Hydrogen potential (pH), and Dissolved oxygen (DO). Other parameters such as COD and TSS were measured in the field with a portable multiparameter spectrophotometer Pastel UV - Secomam. In the laboratory, NTK analysis was carried out using a KJELDAHL PRO-NITRO M distiller, total phosphorus analysis was carried out using a PHARMASPEC UV-1700 spectrometer, and TME analysis (As, Pb and Cd) was carried out using a Varian SpectrAA 110 spectrometer. The different parameters were analysed in the laboratory according to the standards [6].

3. RESULTS AND DISCUSSION

The results of the physico-chemical and metal analyses of the wastewater at the study sites are presented in Table 1.

Table 1. Physico-chemical and metallic characteristics of wastewater at different periods of the study sites

Parameters	Period	Standards [7]	E1	E2	E3	E4	E5	E6	E7
T °C	March 2021	< 40	37.4	30.2	29.9	30	30	37	36.7
	June 2021		32.7	28.6	27.9	29.4	28.9	31.8	32.4
pH	March 2021	5.5 - 8.5	8.44	8.36	9.94	8.21	9.21	9.22	10.68
	June 2021		8.23	8.12	8.45	8.05	8.52	8.32	9.37
DO (mg/L)	March 2021	-	0.82	0.94	0.95	0.95	0.92	0.86	0.85
	June 2021		1.93	2.91	1.98	2.97	1.91	1.92	1.94
TKN (mg/L)	March 2021	50	53	43	47	39	14	47	42
	June 2021		62	67	56	54	34	71	59
Pt (mg/L)	March 2021	15	31.2	22	119.6	34.6	23.7	187.4	69
	June 2021		68.4	51.7	143.9	56.3	45.2	256.6	97.9
DOC (mg/L)	March 2021	300	228.3	136	421.6	557.2	153	659.2	234.2
	June 2021		532.3	378.6	982.1	1043.6	458.5	1358.4	608.7
TSS (mg/L)	March 2021	50	141	64.1	108	209.4	87.3	182.8	62.5
	June 2021		478.3	245.8	395.1	613.4	196.2	570.6	149.5
AS (µg/L)	March 2021	50	0.62	0.54	0.76	0.53	0.67	0.58	0.78
	June 2021		0.71	0.67	0.89	0.62	0.94	0.87	0.91
Cd (µg/L)	March 2021	-	0.32	0.27	0.40	0.29	0.37	0.26	0.24
	June 2021		0.60	0.79	0.64	0.56	0.82	0.45	0.61
Pb (µg/L)	Mars 2021	500	1.26	0.98	1.19	1.32	0.87	1.54	1.44
	June 2021		1.54	1.56	1.99	1.78	1.45	1.79	1.98

T°C: Temperature, TKN: Total Kjeldahl Nitrogen, Pt: Total Phosphorus, DOC: Chemical Oxygen Demand, TSS: Total Suspended Solids, As: Arsenic, Cd: Cadmium, Pb: Lead

According to the results of the analysis, it should be noted that some of the parameters measured have values that do not comply with Ivorian standards for the discharge of wastewater into the natural environment. There is great heterogeneity in the results, showing variations in the degree of pollution from one site to another depending on the season.

Temperature is an important parameter of water quality with important ecological repercussions [8]. It affects density, viscosity, the solubility of gases in water, dissociation of dissolved salts, and influences chemical and biochemical reactions, development, and growth of living organisms in water, especially microorganisms [9]. In the present study, the temperature of the wastewater measured ranged from 27.9°C to 37.4°C, corresponding to the temperature standards for wastewater [7] (Table 1). The highest temperature was observed in the dry season (March 2021) at discharge point E1 and the lowest in the wet season (June 2021) at discharge point E3. The temperature remained high (>30°C) at outfalls E1, E6 and E7 compared to the other sampling points, regardless of the season. These results show that the temperature evolution is not only season-dependent but also sample point-dependent [10]. High temperatures of wastewater discharges pose a risk to the receiving environment because oxygen dissolves better in cold water than in warm water, which will directly result in reduced oxygen solubility and increased odours due to the anaerobic reaction [3].

pH is one of the important parameters in water quality monitoring as it governs most of the chemical reactions that take place in water. It is a measure of the acidity or alkalinity of water. Variations in pH affect many aquatic organisms [11]. The measured pH of the wastewater varied between a minimum of 8.05 and a maximum of 10.68 (Table 1) and shows that the water remained alkaline throughout the study seasons. According to [12], an alkaline pH favours the precipitation of most metals as insoluble solids. The highest pH value was observed in the dry season (March 2021) at discharge point E7 and the lowest in the wet season (June 2021) at discharge point E4. The pH values obtained during the study revealed that the effluent from some of the outfalls exceeded the Ivorian reference standards (5.5-8.5) for wastewater [7].

The dissolved oxygen concentrations of the wastewater vary from 0.82 to 2.97 mg/L (Table 1), in all the points studied, this dissolved oxygen concentration remains low. The highest oxygen content is obtained at point E4 in the rainy season and the lowest at point E1 in the dry season. These high levels in the rainy season may be due to the observed seasonal variation [10]. Oxygen has limited solubility in water inversely related to water temperature and salinity [13]. The low dissolved oxygen concentrations in the wastewater studied are indicative of high microbial activity in the water due to the presence of biodegradable organic compounds in the discharge [14].

In the wastewater of the city of Grand-Bassam studied, the concentrations of nitrogen TKN fluctuate between a minimum of 14 mg/L and a maximum of 71 mg/L (Table 1) in March 2021 and June 2021 respectively. The TKN values obtained during this study revealed that the wastewater from some discharge points exceeded the Ivorian reference standards (50 mg/L) for wastewater [7]. The variation in TKN shows that the rainy season is the period of high concentrations of these elements in wastewater. The TKN levels in the wastewater from this study are lower than those found in the work [15] on raw wastewater from the Abidjan sewer system.

The total phosphorus concentrations of the studied wastewater vary between 22 mg/L and 256.6 mg/L (Table 1). Total phosphorus levels remained high during the two study seasons and exceeded the Ivorian standard of 15 mg/L [7] at all study stations. These results show that the evolution of phosphorus is not only a function of the season but also depends on the sampling point. The total phosphorus levels obtained in this study remain much higher than those obtained in the work [15] on raw wastewater from the Abidjan sewer system.

Chemical oxygen demand is a parameter that measures the organic matter contained in a sample of natural or wastewater, whether it is biodegradable or not [16]. The COD values observed in the wastewater at the various measurement points show a significant variation with a minimum of 136 mg/L at point E2 and a maximum of 1358.4 mg/L at point E6 in March 2021 and June 2021 respectively (Table 1). The seasonal variation of COD shows that the rainy season remains the period of high concentrations of COD in wastewater. This high concentration of COD in the rainy season is said to be the consequence of enrichment of the wastewater in organic matter that could not be decomposed by microbial activity [17]. The origin of this organic matter in the rainy season could be attributed to runoff water, rich in organic and inorganic substances discharged into the pipes [18]. The COD values obtained during this study revealed that the wastewater from some discharge points exceeded the Ivorian reference standards (300 mg/L) for wastewater [7].

Suspended solids are one of the important parameters in wastewater characterization [19]. They are used to describe the extent of pollution and remain good indicators of water turbidity [20]. The suspended solids concentrations obtained in the present study varied from 62.5 mg/L at point E7 to 613.4 mg/L at point E4 in March 2021 and June 2021, respectively (Table 1). The seasonal variation shows that the high values of suspended solids are obtained in the rainy season. These high levels of suspended solids in the rainy season would be the consequence of enrichment of the runoff water rich in inorganic particulate matter that has been discharged into the wastewater pipes. The suspended solids values in this study remain above the Ivorian wastewater discharge standard of 50 mg/L [7] at all study stations throughout the study period. This enrichment of wastewater in suspended solids increases water temperature and a drop in dissolved oxygen [21].

Trace metals are potentially toxic to organisms even at low concentrations [22]. They are not biodegradable and tend to accumulate in aquatic organisms [23]. The main way in which trace elements enter the human body system is through the oral route. Consumption of agricultural products irrigated with untreated or partially treated wastewater exposes to various trace element diseases [14]. Cd levels in analysed wastewater vary from 0.24 to 0.82 µg/L. They fluctuate respectively for Pb from 0.87 to 1.99 µg/L and from 0.53 to 0.94 µg/L for AS (Table 1). The various metal concentrations observed in the wastewater remained low at all sampling points during the two study seasons. The concentrations of Pb and As correspond to Ivorian wastewater discharge standards [7].

3.1. RELATIONSHIPS BETWEEN VARIOUS PARAMETERS

Pearson correlation was used to highlight the relationships between the different parameters studied. Table 2 shows the correlation coefficients between the different parameters.

Table 2. Correlation matrix of physico-chemical parameters of wastewater

Variables	T°C	pH	DO	NTK	Pt	DOC	TSS	AS	Cd	Pb
T°C	**1**									
pH	0,26	**1**								
DO	**-0,98****	-0,20	**1**							
NTK	0,45	-0,05	-0,37	**1**						
Pt	0,35	0,41	-0,18	0,37	**1**					
DOC	0,11	-0,04	0,07	0,33	0,73	**1**				
TSS	0,01	-0,57	0,06	0,22	0,29	**0,79***	**1**			
AS	0,16	**0,91****	-0,18	-0,07	0,18	-0,25	-0,60	**1**		
Cd	-0,50	0,02	0,40	-0,31	-0,08	-0,13	0,03	0,33	**1**	
Pb	0,67	0,29	-0,52	0,62	0,65	0,70	0,39	0,07	-0,55	**1**

** P= 0.05, ** P=0.01 significant correlation (two-tailed)*

In Table 2, the correlation coefficients have shown links between various parameters with similar characteristics. There is a significant negative correlation between temperature and DO (r=-0.98, p<0.01). This relationship shows that the high temperature of the wastewater is the main cause of low oxygen dissolution. A significant positive correlation (r=0.91, p<0.01) is observed between pH and AS. Finally, there is a significant positive correlation of COD with TSS (r=0.79, p<0.05). This result shows that the suspended solids are loaded with organic matter. The parameters TKN, Pt, Cd and Pb do not show a significant correlation with the other parameters studied, which suggests a diffuse origin of these parameters in the analysed wastewater [10].

4. CONCLUSION

This study made it possible to evaluate, in urban wastewater, certain physico-chemical and metallic parameters, which can be indicators of the origin of water pollution in the Ouladine lagoon. On each of the seven sites studied, some values of the parameters studied showed very strong fluctuations according to the season and the site. According to the analyses carried out, all the wastewater from the seven sampling points had an alkaline pH (pH>8), a high load of oxidizable matter (COD), suspended solids (TSS), total phosphorus (Pt) and total Kjeldahl nitrogen (TKN). Some of these values exceed the limit values recommended by Ivorian regulations for wastewater. As for metal contents, they remained low at all sampling points during the two study seasons, thus corresponding to Ivorian standards. The discharge of urban wastewater without prior treatment can lead to the contamination of the Ouladine lagoon and consequently cause significant harm to aquatic resources. According to the results of this study, a municipal wastewater treatment system must be set up to discharge a liquid effluent that complies with Ivorian regulatory requirements.

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