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Contribution to Management of Wastewater of Yamoussoukro City: Impact of Wastewater Treatment Plants Failure on Environmental Pollution of The Lakes

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Abstract:
This study, conducted on the sanitation system and the artificial receptor (lakes) of Yamoussoukro environment system was used to evaluate the treatment capacity of wastewater treatment plants (STEP), volumes of wastewater and sludge from urban area this city. The treatment capacity varies between 250 and 2000 equivalent inhabitants (EH). The flow volume of wastewater passing through the STEP is 1597 m^3/day. This volume flow generates an annual contribution of mud around 1492 m^3 in receiving environments. Diagnosis is noted that only 20% of STEP are functional and 80% others are dysfunctional. The concentration of MES (suspended matter), BOD_5, COD, total nitrogen, total phosphorus and nitrate are higher than the limit values normalized.

Keywords*: station, sewage, wastewater, fecal coliform ,pollution, lake, processing, receiving water-sanitation*

Introduction

The city of Yamoussoukro, the political capital of Côte d' Ivoire, has public sanitation facilities that are mostly non-functional. One of the major problems of cities in developing countries is the ability or willingness of governments to maintain infrastructure in good working condition. Besides roads, public buildings, maintenance of sewerage lags behind. There is flooding in our country simply because the network of storm water drainage is obstructed by sand and garbage of all kinds. The wastewater should first be treated before reaching the receiving environment (artificial lakes) are not in reality. Because wastewater treatment plants(STEP) designed to remove wastewater (EU) organic fillers, MES and others are 80% stopped because of lack of maintenance. The discharged water does not therefore in the discharge standards set by national and international legislation. Consequently, these lakes now have a serious pollution in many forms: siltation, eutrophication thrust, the release of odors, the proliferation of mosquitoes and the resurgence of waterborne diseases. A diagnostic study of the sewerage system will assess and quantify the impact of treatment on receiving environments stations. Description and identification of purification performance of wastewater treatment plants and quantification of the volume of wastewater and sludge treatment plants. To make this work, we carried out the study of sanitation facilities, the quality of wastewater and surface water.

1. Materials And Methods

All artificial lakes and water treatment plants has been visited. Physicochemical and biological analyzes were performed on all STEP and lakes. Meetings with some project owners of these stations and resource persons were held to gather information on those books and historical.

1.1. Presentation Of The Study Area

The Commune of Yamoussoukro covers 400 km2. For cons, the urban portion has been Director of Development Plan (PDU) extends over an area of 270 km2. This study focuses only on urban areas.

1.1.1. Location

The Commune of Yamoussoukro is located in the center of the country between 6 ° 40 'and 7 ° north latitude and between 5 ° 10' and 5 ° 20 'west longitude (BNETD, 1997). It is located at a distance of 260 km north of Abidjan, at the intersection of roads leading to the cities of Daloa, Bouake, Oumé of Didiévi and Sinfra . Yamoussoukro enjoys a favorable geographic location (BCEOM, 1997).

1.1.2. Population And Habitat

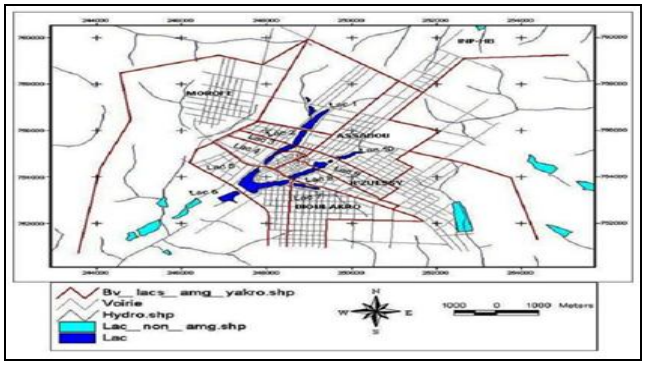
The population of the urban area of Yamoussoukro increased from 8,020 inhabitants in 1965 to 35,585 inhabitants in 1975 to reach 110,013 inhabitants in 1988. The 1998 census counted 176,109 (RGPH 1998) inhabitants. Estimated for the year 2012 with an average increase of 4 % for area Yamoussoukro rate population is 304,964 inhabitants. The type of habitat Common Yamoussoukro can be classified into three categories that are home to luxury, economic and scalable habitat. The city of Yamoussoukro includes ten (10) districts, ten (10) villages, eight (08) Administrative housing estates. The urban area covers the same areas of the City with the exception of four (4) communal villages.

1.1.3. Local Economy

The city of Yamoussoukro received exceptional modern urban plan, and futuristic making it one of the most attractive cities in the country. It offers a nice cityscape with tall buildings in the ostentatious architecture such as Félix Houphouët Boigny Foundation for Peace Research, the Basilica of Our Lady of Peace, large schools. Its economy is dominated by the service sector (67 %) followed by secondary (16%), primary (10 %) and other activities (7%). The tertiary sector (administration, education, research, services, trade, transportation and tourism) is experiencing a boom due to the urbanization of the city, the population growth and particularly to an early implementation effective transfer of the capital.

1.1.4. Physical Characteristics

The Commune of Yamoussoukro is full of many natural lakes and undeveloped. Besides these, the Commune has a lake system consists of ten (10) Artificial lakes and groundscaped the surface of the water is 140 hectares (PARINET B. et al, 2000).



Map 1: Lakes system of Yamoussoukro

The flow of water from one lake to the other and gravity is through the works of communication. At these communication structures, the overflow immediate upstream lake which flows into the adjacent downstream lake. The watershed of this lake system covers 56.28 km2 and is integrated into the planning of the city that covers 270 km^2blueprint. The terrain is slightly hilly, the average altitude is 200 meters. It is characterized by plateaus in clay, granite and sandy soils in place. Geotechnically a layer of lateritic gravel gravelly occurs from 0.3 m to 1.5 m depth. This becomes gravelly clay from 1.5 m depth. The Commune of Yamoussoukro belongs to the humid tropical climate zone characterized by two dry seasons and two rainy seasons. Over the period 2001-2010, the maximum and minimum monthly mean temperature values are 33.05 ° C and 19.55 ° C (N'GUESSAN, 2011). The hottest time of year in Yamoussoukro is the first quarter (January to March), while the least hot period is the period from July to August In addition, the annual rainfall varies from 1000 to 1600 mm of water. Also, the vegetation is characterized by it pre- forest savannas become forest galleries along the rivers (BNETD, 1997). The city of Yamoussoukro has a Master Plan of Urban (PDU) approved and declared a public utility through Decree No. 97-177 of 19 March 1997 on the approval and declaration of public utility project scope of urbanization of the city of Yamoussoukro.

2. Building Sanitation System Study

2.1. Technical And Operating Data Management Stations Sewage

All sewage from the city of Yamoussoukro stations operate according to the purifying principle based on biological treatment with three variants are:

- Scrubbing extended aeration activated sludge;
- Purification under anaerobic conditions;
- Purification on a fixed biomass (filterbed)

Technical characteristics, mode of management, current operating status of these stations and the receiving environments in which they reject the treated water are shown in Table 1. It is noted that of the 24 sewage of the city of Yamoussoukro stations, only five (5) are in working condition. The other stations are not functional and reject all their effluent into groundscaped lakes or on the ground.

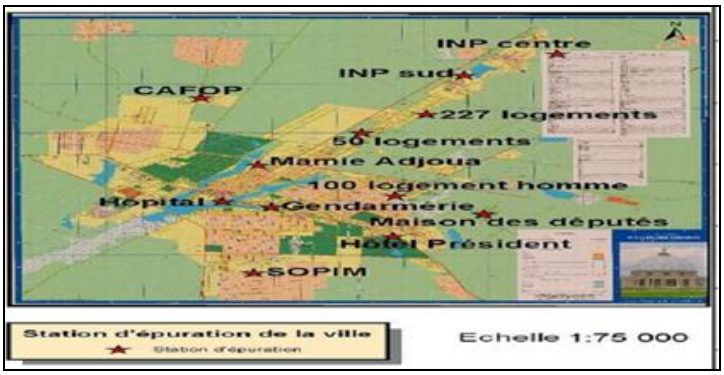
2.2. Capacity Treatment Plants

Figures 1 and 2 show the capacity of sewage and waste water volumes and mud that transit stations. These stations have a capacity ranging from 250 to 2 000 (EH) population equivalent. Volumes of wastewater daily that transit fluctuate between 17 (STEP CHR) and 290 m3 (STEP Scientific High School Boys + 100 lodgments)

Areas where production volumes of wastewater and sludge highest on record are the Scientific School, North INP, INP Centre and South. Considering the urban area, the total volume of wastewater discharged into receiving waters of the District of Yamoussoukro is 1597 m3 per day, or an annual volume of 582,905 m^3. The volume of wastewater generates an annual intake of 1,432 m3 of sludge in the receiving environment due to the non-functional state of wastewater treatment plants

Step	Sites	Principle Used In Websites	State	Milieu Récepteur
1	INP sud	Actived mud	Functionnal	Lake unamenaged
2	INP centre			Lake unamenaged
3	Hôtel Président tour (140 chambres)			Lac du golf
4	Hôtel parlementaire (310 chambres)			Lake unamenaged
5	CHR (130 lits)	filter bed		Lac n°5
6	INP nord	HS (raccorded to INP centre		
7	227 lodgment 1	Actived mudventilation	Nonfunctionnal	Ground
8	227lodgment 2	Decanter digester		
9	Lycée scientifique (1000 élèves)	Actived mudextended aeration		Lake unamenaged
	100 lodgmentman			
10	CAFOP (école)			Ground
11	39 lodgment			Bas-fond
	80 lodgment			
12	64 lodgment	Actived mud extended aeration		Ground
13	SOPIM			Ground
14	33 lodgment			Lake n°10
15	50 lodgment	Decanter digester		Ground
16	100 lodgment filles			
17	Lycée Mamie ADJOUA (1500 élèves)			Lake n°2
18	Palais présidentiel	Actived mud extended aeration		Lake n°2
19	Villa des hôtes			Lake n°2
20	Bâtiments techniques et lodgment			Lake n°2
21	Villas des parents de FHB			Lake n°1
22	Préfecture	Decanter digester		Lake n°1
23	Gendarmerie	Actived mud extended aeration		Lake n°7
24	Centre commercial Mofaitai			Lake n°7

Table 1: Technical specifications and administration of STEP

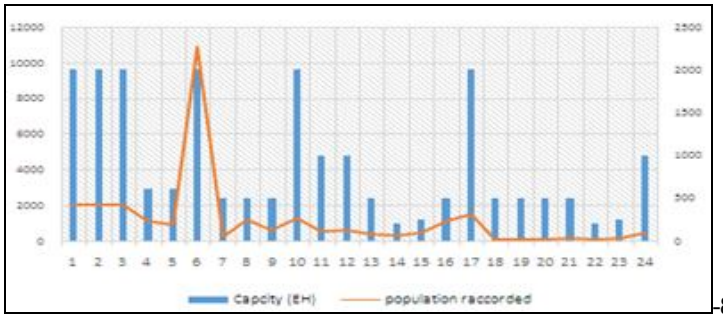


Map 2: Sampling point wastewater

2.3 Performance Purification Treatment Plants

On the ground, the entire sewage from the city of Yamoussoukro stations could not be visited due to inaccessibility (abandoned in the bushes) or lack of obtaining permission to access them.

Thus, of the 24 stations planned, 17 have been visited and have been sampling for assessment of their treatment performance. These stations INP North, INP Centre, INP South, 227 lodgments 1, 227 lodgment 2, CAFOP School, 39 and 80 units of SOPIM , the President Hotel and Tower Buildings , Hotel Parliamentarians , CHR , 33 lodgments, 50 lodgments, housing 100 girls , Lycée Mamie Adjoua, Prefecture Region Aries and the Force. Among these STEP, only those of the INP Centre, INP – South, Hotel Parliamentarians and CHR work. Note that, although the treatment plant INP North is non-functional, the arrival of wastewater from this area is connected to the station INP Centre where they undergo treatment before be discharged into the receiving environment. For a better analysis of the purification performance of STEP, the results are presented in two parts: the purification performance for functional STEP and the quality of waste water exiting the STEP and discharged into receiving waters.



-85+96

Figure 1: Capacity of WWTP compared to people number raccorded

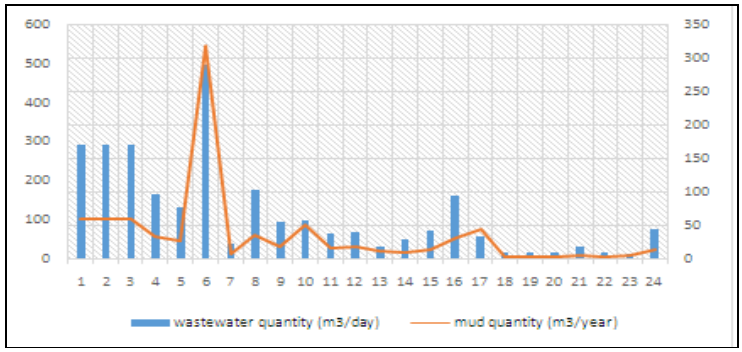


Figure 2: Wastewater and mud producted per WWTP

3. Study Of The Quality Of Surface Waters

The study of the quality of surface waters is performed on the 10 artificial lakes. Nineteen (19) lake water samples were collected and analyzed. Table 4 and Map 2 below show respectively the coordinates of the sampling points of lake water Yamoussoukro and location.

3.1. Microbial Analysis Of Lakes

3.1.1. Sampling Method

Samples were taken from the care of laboratory LAPISEN then transferred quantitatively in coolers containing ice packs. Samples were collected in sterile glass vials white 500ml and 1000ml containing sodium thiosulfate. The temperature at the reception of the water sample is 4.13 ° C.

3.1.2. Method of analysis

The reception, recording and storage of the samples in a refrigerator are performed at a temperature between 3 ° C and 8 ° C until analysis. The conditions under which the test were performed according to the method of analysis are from NF EN ISO 9308-1 (2002) and NF EN ISO 19250 (2010).

Map2: Geographical location of the sampling points of lake water Yamoussoukro

3.1.3. Test Results

The test results of the microbiological testing are shown in Table 2 below.

Parameter	lake1	lake2	lake3	lake4	lake5	lake6	lake7	lake8	lake9	lake10	Normes
Fecal Coliformsbacteria 37°C/24h UFC/100ml	915	980	1500	10000	880	1000	8200	6200	5700	9400	0
Thermo tolerant coliforms 44°C/24h UFC/100ml	550	740	1300	3200	790	470	7700	4100	2300	5400	<400
Salmonella spp in 100ml	absent	absent	absent	absent	absent	absent	present	present	present	present	

Table 2: Results of microbiological analysis of samples taken from lakes

3.2 Interpretation Of Results Of Analyses Microbiological And Physicochemical Lakes

The waters of the ten lakes Yamoussoukro, used by gardeners for watering plots are so polluted that they are used to power plants are now unfit for consumption. The analysis made by the FAO (Food Background World) in 2005 as part of a major support to the development of urban and peri-urban horticulture project , showed a very high level of contamination of the water used by three main bacteria namely coliform bacteria , thermo tolerant coliforms and salmonella. In the analysis of Table 2, the number of coliforms measured in 10 lakes bacteria varies from 3.5 10^2UFC/100ml(Lake 6) 1.6 UFC/100ml(Lake 5). This high rate of microbiological pollution is due to the fact that many human activities are carried out in the vicinity of lakes in the city of Yamoussoukro. These include market gardens and rice in some shallows, trade with developing scrub, bars and restaurants that discharge into lakes. All discharges are causing pollution of these lakes. This rate of microbiological pollution of lakes is confirmed by the measured values of thermo tolerant coliforms or fecal coliforms. Indeed, the lakes also contain high amounts of thermo tolerant coliforms evaluated - beyond the permissible value (<400 UFC/100 ml). These amounts vary from $2.3.10^2$ UFC ml (downstream side of the lake 6) and $7.7.10^3$ UFC ml (upstream side of the lake 7). These quantities of microbiological pollution of lakes city lead to eutrophication. Eutrophication is generally used to describe the excessive enrichment of a body of water by artificial and undesirable input of nutrients promoting plant growth. The aquatic environment is a living environment, governed by complex balance between a wide variety of plant and animal organisms. As for Salmonella spp which are rod-shaped bacteria and harmful to humans and some animals, including rodents, birds and domestic animals , the results of laboratory measurements shows their actual presence in lakes 5, 6 , 7, 8 , 9, 10 and the downstream side . Lakes 1, 2, 3, 4 and 10 are devoid of the upstream side Salmonella spp .

In the absence of disturbance, the system is generally balanced, and it appears regulation between producers, consumers and decomposers self. But if the environment receives excessive nutrient inputs (phosphates, nitrates, ...) its ecological balance can break . Then we witness a proliferation of plant material that accumulates on the site, and that is likely to significantly alter the characteristics of the environment and move its physicochemical equilibria.

Indeed, the lakes of the city of Yamoussoukro face a physicochemical pollution, which could worsen in the long run due to their greater exposure to human activities. At the current state, they have a physicochemical pollution moderate compared to microbiological pollution.

These waters retain their neutrality with pH between 6.5 and 8.5 and also retain their natural character for the physical parameters. The water temperatures are above 25 ° C. The waters are weakly mineralized with concentrations of dissolved salts and relatively low conductivity that is to say less than 300 S / cm. This is a sign of increased inputs of dissolved substances from the watershed. This explains the poverty of water calcium ions (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), sulfate (SO_4^{2-}) and chloride (Cl^{-}) in lakes. Nitrite nitrogen compounds are soluble in water which are formed in a basin when the microbiological degradation of nutrients is incomplete. Their presence may also be due to a supply of water loaded with nitrites or storm water (especially after storms). When a pond ecosystem is intact, the water analysis should detect any nitrite. Even at very low concentration (0.2 mg / l), nitrite can have extremely negative effects on a pond and poison all the fish it contains. Lake 10 for example, present toxicity due to its very high nitrite concentration of which is 35 mg / L.

This toxicity is due mainly to the fact that binding in the blood, nitrite prevents the transport of oxygen. Fish are therefore at risk of asphyxiation. The pH value plays an important role in this regard. When the content of water is high in nitrites, toxicity to the population of a basin is even greater than the pH is lower.

Concentrations of ammonium and nitrate are also indicators of the nitrite content. If they are too high, biological equilibrium balance is disturbed. This is the case of lakes 5, 6, 7, 9 and 10 which have concentrations higher than 0.5 mg /L ammonium and 0.1 mg /L for nitrates in all lakes in such cases, there is too little of denitrifying microorganisms in ponds or bacteria have been damaged and are no longer able to perform their function properly. Phosphates are essential food algae. The value limit of the content of phosphates basin is close to 0.03 mg / l, and the slightest increase can trigger an outbreak of algae. Phosphates from food distributed to fish (all fish food contain a certain percentage of phosphates) or filling the basin with water loaded with phosphates. Suspended solids include all inorganic or organic materials which do not dissolve in water. The amounts recorded in lakes 1, 7 and 10 (above 50 mg / L) show that clays, sands, silt, organic and inorganic materials of small size, plankton and other microorganisms are contained in these. Lakes. These materials affect the transparency of the water and reduce the penetration of light and therefore, photosynthesis. They can also interfere with the respiration of fish.

4. Study Of The Quality Of Wastewater

20 of sample points have been identified for waste water at the inlet and at the outlet of each treatment facility. The samples of raw wastewater and treated wastewater were taken respectively for analysis of the physicochemical parameters such as temperature (T ° C) , pH and suspended solids (SS) , the chemical oxygen demand (COD), biological oxygen demand (BOD_5) , the total phosphorus , phosphate, sulfate , chloride, calcium, nitrite (NO_2^-) and nitrate (NO_3^-) . Note that the sampling is performed at the water inlet and outlet of the treatment station where it is functional. In case of malfunction of the station, the sampling is done only at the entrance to the station. Map2 presents wastewater sampling points.

4.1. Performance Purifying

Based on the results of the analysis of the parameters, the purifying efficiency, from which the purification performance of wastewater treatment plants was evaluated, were calculated using the following equation.

$$\text{Purification yield (\%)} = \frac{Xeru - Xf}{\text{Xeru}} 100$$

Xeru = Concentration parameter considered in the raw waste water (mg / L);
Xf = Concentration of the parameter considered in the treated water (mg / L).

4.2. Performance Of Wastewater Treatment Plant Functional

Overall, the incoming sewage into functional STEP (INP Center, INP South, Hotel Parliamentarians and CHR) are slightly alkaline ($7.3 \leq pH \leq 8.6$) . At the end of STEP, the pH of the wastewater decreased slightly to move towards neutrality. Wastewater treated by the STEP and discharged into receiving waters meet the threshold values ($5.5 \leq pH \leq 8.5$) shown in the regulation of discharges and emissions of installations classified for environmental protection in Côte d ' Ivoire (Ministry of Environment, Water and Forests, 2008).The sewage inlet and outlet of the STEP have substantially identical temperatures. They revolve around 30 ° C and are consistent with the values prescribed by the Ministry of Environment, Safety and Sustainable Urban Development. Overall, we note that the pollution load in the waste water entering the STEP decreases dramatically the output thereof. The wastewater quality is improved to the output of STEP. Considering the major parameters of organic pollution and nutrients from sewage, we can notice that:

- Suspended solids (MES) are reduced from 5.68 to 97.17 % in the functional STEP. These reject treated wastewater containing MES concentrations varying between 3 and 83 mg / L. These MES concentrations are much lower than the limit value (≤ 150 mg / L) specified in the regulation of wastewater discharges in Côte d' Ivoire;
- The reduction of chemical oxygen demand (COD) and biochemical oxygen demand (BOD_5) in STEP investigated is very high. It oscillates between 69.29 and 94.99 and between 70.19 % and 94.84 %, respectively for COD and BOD_5. Treated wastewater being dumped into receiving waters have concentrations between 30 and 152 mg O2 / L and between 5 and 47.1 mg / L respectively. These treated water meet the threshold values (≤ 300 mg O2 / L for COD and ≤ 150 mg / L for BOD_5) specified in the regulation of discharges and emissions classified for environmental protection facilities in Côte d'Ivoire
- With respect to total phosphorus, a reduction of 16 to 90.5 % is observed in the STEP. Its concentration in effluents discharged into receiving waters is between 0.38 and 5 mg / L. This concentration is much lower than the limit value (≤ 15 mg / L) specified in the regulation of water discharges waste in Côte d' Ivoire;

- 37.5 to 91.5 % of total nitrogen is removed in different STEP investigated. Waste water coming out of these STEP contain total nitrogen concentrations ranging between 34 and 400 mg / L. This wastewater meet the standards of wastewater discharges in Côte d' Ivoire (≤ 50 mg / L) with the exception of those rejected by the STEP INP Centre (400 mg / L);
- Except STEP Hotel parliamentarians where nitrate leaching is observed in treated wastewater, functional STEP significantly reduce the concentration of nitrate in wastewater discharged into receiving waters. The purifying yields fluctuate between 81.41 and 97.10 %. In sum, the INP South sewage treatment plants INP Center, Hotel Parliamentarians and CHR significantly reduce the pollution load of wastewater produced in these areas and discharge into receiving waters of wastewater processed that meet the standards specified in the regulation of discharges and emissions of installations classified for environmental protection in Côte d' Ivoire. Among these stations, that the CHR, which is composed of a filter bed, seems more efficient to remove organic pollutants and nutrients from the wastewater. Table 9 on page 39 shows the results of the wastewater quality at the entrance and exit of sewage INP Centre stations, the INP-South Hotel Parliamentarians and the hospital (CHR) and the purifying efficiency of these stations.

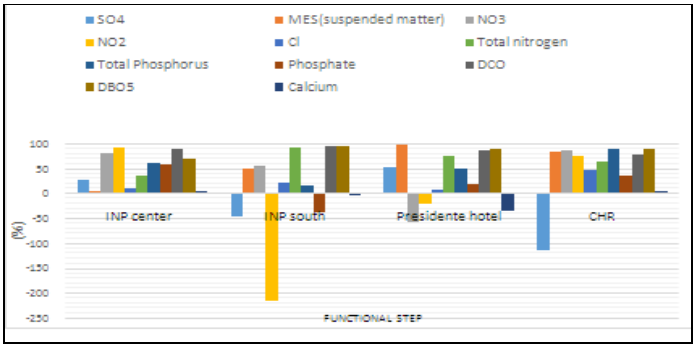


Figure 3: Treatment efficiency of functional step

4.3. Test Results Physical And Chemical Wastewater

The test of the physicochemical wastewater analysis results are shown in Table 3,

n° of STEP	MES (mg/L)	Total Nitrogen (mg of N/L)	Total Phosphate (mg of P/L)	DCO (mg of O_2/L)	DBO5 (mg of O_2/L)
7	210	800	12,5	476	153
8	37	560	3,75	100	30,5
10	4	100	0,5	<30	7,62
11	117	600	7,5	<30	<5
13	687	500	7,5	2780	861
14	65	60	1,25	343	101
15	352	1500	20	79,4	25,4
16	90	860	11,5	305	91,5
17	78	100	2,75	117	36,2
22	52	140	2,33	<30	7,38
23	28	93	100	104	30,8
NORMES	**≤150**	**≤50**	**≤15**	**≤300**	**≤150**

Table 3: Results of physicochemical analysis of samples from wastewater Yamoussoukro

4.4. Interpretation Of Results Of Physical And Chemical Analysis Of Wastewater

Table 3 above shows the results of the quality of wastewater discharged into receiving waters. Such wastewater has a pH between 6.7 and 8.5. The pH of these waters meet the discharge standards (5.5 ≤ pH ≤ 8.5) shown in the regulation of discharges and emissions of installations classified for environmental protection in Côte d' Ivoire. Wastewater arriving in receiving waters has a temperature that ranges between 26.7 and 30.8 ° C. These values are consistent with the standards of wastewater discharge in Côte d'Ivoire in relation to the temperature [T (° C) ≤ 40 ° C]. Considering the major parameters of organic pollution and nutrients, it can be observed that the concentrations of suspended matter in wastewater discharged into the receiving environment of the city of Yamoussoukro vary between 3 and 687 mg / L. The highest concentrations are recorded at the output of the 227 lodgment1STEP(210 mg / L), the President Hotel (178 mg / L) of SOPIM (687 mg / L) and 50 lodgment(355 mg / L). These concentrations are higher than the limit value (≤ 150 mg / L) specified in the regulation of wastewater discharges in Côte d' Ivoire. Regarding the COD and BOD5 concentrations recorded at the output of STEP are highly variable. They are comprised respectively between 30 and 2780 mg O2 / L and 5 to 861 mg / L. At the end of treatment 227 units # 1 stations , housing 100

girls, 33 units , Hotel President and SOPIM , wastewater discharges do not meet the discharge standards recommended in the regulation of discharges and emissions of installations classified on COD ($\leq$ 300 mg O_2 / L) . The situation is the same for BOD5 ($\leq$ 150 mg O_2 / L)at the output of the 227 lodgment1STEP, Hotel President and SOPIM. For nutrients, wastewater discharged into receiving waters is heavily loaded with total nitrogen. The total nitrogen concentrations recorded at the output of most treatment plants investigated are much higher than the limit value ($\leq$ 50 mg / L) recommended by the regulation of discharges and emissions of installations classified for the protection of the environment in Côte d' Ivoire. This massive supply of nitrogen to receiving waters enriches the nutrient, which would cause eutrophication. This situation would be exacerbated by the high concentrations of nitrate contained in the wastewater discharged from sewage treatment plants to receiving waters. However, it should be noted that the wastewater from the STEP contain total phosphorus concentrations that are consistent with standards of wastewater discharge in Côte d' Ivoire ($\leq$ 15 mg / L).

5. Conclusion And Recommendations

The present study assessed the capacity of treatment of the urban area of the District of Yamoussoukro and the volumes of waste water and mud that transit stations. Also, it helped to determine the treatment performance of these treatment plants. These stations have a capacity ranging between 250 and 2000 (EH) population equivalent. The volume of waste water that passes to be released into receiving waters is 1,597 m3 per day, or an annual volume of 582,905 m^3. The volume of wastewater generates an annual intake of 1,432 m3 of sludge in receiving environments.

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