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Assessment of Wastewater Management at the Etoudi Slaughterhouse in the Municipality of Yaoundé - Cameroon

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Abstract: The management of wastewater in developing countries is a crucial challenge. The overall objective of this study was to evaluate the impact of discharges from the slaughterhouse Etoudi on physico-chemical and bacteriological water quality of the Ako'o. This study was conducted in two phases. The first phase (preliminary) in April 2022, during which a prospecting along the rivers and its watershed was performed. The second phase extended from May to October 2022, was dedicated in the collection of hydrological data, samples of water samples and bacteriological at each station coupled to the data analysis. This wastewater were collected from different stations, stored in refrigerated cooler and brought back to the laboratory for monitoring physical, chemical and bacteriological parameters according to standard protocols. The results show the effluent discharges from the slaughterhouse Etoudi exhibit high levels of pollution physicochemical (CND, MES, NO_3, NH_4^+, PO_4^{3-}, COD and BOD 5) and bacteriological (CF and SF) in the receiving environment having a negative impact on the watercourse Ako'o. negative impacts were increased to 90% by the dunghill faeces oxen or invading the rights of way areas. Existing gutters are littered with faeces of any kind and are not priests. Which causes recurring floods during the rainy season, the proliferation of insects and rodents and the emanation of foul odors and the persistence of certain diseases such as malaria typhoid fever, dysentery etc. this wastewater join the River Ako'o. This constitutes a major source of environmental pollution in general and rivers of waters Ako'o in particular. The positive impacts threshold is the use of cattle feces for farming populations who find themselves in different fields. Effluent discharges from the slaughterhouse Etoudi present an environmental and health risk because of high concentrations of physicochemical and bacteriological pollutants. A treatment system is needed to ensure environmental and health safety.

Keywords: Waste Water, Slaughterhouse, Impact, Environment, Etoudi

1. Introduction

The treatment of wastewater before it is released into the environment is a major challenge for many countries in the world [1, 2]. This difficulty is more prominent in developing countries, which not only suffer from a lack of capital, but are confronted with anarchic urbanisation and industrialisation. In Africa, the situation of wastewater disposal and treatment is dramatic. Most of the sewage networks connected to mechanised treatment plants set up after independence are now non-functional and the raw sewage produced is evacuated into the shallows [3]. However, a number of studies highlight the negative consequences of poor sanitation, both in terms of health, environment and economy. Chevalier mentioned that

hundreds of millions of people worldwide suffer from schistosomiasis, cholera, typhoid fever, worms causing various health disorders and other infectious diseases [4]. In addition, 3.5 million children die each year from diarrhoea, due to poor sanitary conditions [5]. According to recent studies, 51% of African countries have severe environmental pollution that threatens water sources [2].

In Cameroon, most of the wastewater from agglomerations and industrial structures is now discharged into the natural environment without prior treatment. Indeed, almost all wastewater treatment plants have been out of order, overloaded or abandoned for over a decade [6]. The new law on the water regime stipulates in its article 4 that: "are forbidden the dumping, flowing, throwing, infiltration, burying, spreading, direct or indirect deposit in waters of any solid, liquid or gaseous matter and in particular industrial, agricultural and atomic wastes likely to alter the quality of surface or underground waters, or sea waters within the territorial limits; to harm public health as well as aquatic or submarine fauna and flora; to jeopardize the economic and tourist development of the regions" [7, 8]. Hence, companies such as breweries, sugar factories, food processing and treatment plants, tanneries including slaughterhouses discharge large quantities of organic waste into the waterways without prior treatment [3]. These phenomena affect and modify the aquatic environments in most of our cities and particularly in Yaoundé.

Several studies have been carried out on aquatic ecosystems located in urban areas in the Yaoundé region [9, 10]. From this work, it emerges that all the watercourses in the Mfoundi catchment area are subject to organic pollution of anthropogenic origin, as a result of their use for the evacuation of waste from the city and industries [6, 11]. The city of Yaoundé is irrigated by a dense hydrographic network, including the Ako'o river in its northern part. In its middle course, this watercourse receives the effluent from the Etoudi slaughterhouse. Slaughterhouses are probably the typical example of industries where water is used for the washing of by-products and the elimination of waste (faeces, rumen and blood debris). This water is usually loaded with organic matter and therefore becomes an important source of pollution for the receiving environment [12]. The daily discharge of this untreated effluent from the slaughterhouse into the watercourse could lead to a negative impact on the environment. This could be a threat to the biodiversity of the water body and pose a public health problem for the neighboring population.

This study carried out on the slaughterhouse's discharges aimed to assess its environmental and social impacts in order to ensure its sustainability. The general objective is to assess the impact of wastewater discharges from the Etoudi slaughterhouse on the natural and human components of the environment of the Santa district.

More specifically, it aims to take an overview of wastewater management at the Etoudi slaughterhouse and characterise the wastewater from the slaughterhouse to identify its pollution level.

2. Materials and Methods

2.1. Overview of Effluent Management at the Etoudi Slaughterhouse

The field trips made it possible to collect information on the management of effluents (wastewater) at the Etoudi slaughterhouse from the staff and the population using survey, interview and observation techniques.

For data collection, a survey of the slaughterhouse staff was carried out inside and outside the slaughterhouse. A semi-structured questionnaire was administered to the staff of the slaughterhouse and to people in the vicinity of the study site. These surveys were carried out following the survey and polling techniques proposed by Bassompierre [13]. The purpose of the survey is to collect the opinions of the population and staff on the wastewater management system and its impacts on the environment and health.

2.2. Physicochemical Characteristics of the Slaughterhouse Discharges to Identify Its Pollution Load

Suspended solids are determined by the so-called "photometric" method. The wastewater sample is taken in a 25 ml cell and placed in the Hach DR/2010 spectrophotometer. The TSS content with reference to a control, which is distilled water, is read directly on the digital display in mg/l, at wavelength 810 nm.

The measurement of the chemical oxygen demand is done by the so-called "reactor digestion" method. After homogenisation of the wastewater samples, 2 ml are taken and introduced into COD tubes, then incubated in the presence of a control at 150°C for 2 hours in a Hach COD reactor (multi-tube heater). After cooling the tubes, the COD value of the sample is read in mg/l, using a Hach DR/2010 spectrophotometer, at a wavelength of 600 nm [14].

In the laboratory, 157 ml of sample contained in an opaque BOD5 bottle was incubated at 20°C in a LIEBHERR BOD analyser. Three to four grains of KOH were introduced into the hollow cap of the bottle and absorbed the CO2 released. The rise in mercury in the manometer tube corresponding to the quantity of oxygen consumed by the bacteria was read every day for 5 days. BOD5 is expressed in mg/L oxygen [15].

The pH and redox potential (Eh) measurements were determined using a Hach pH meter (HQ11d). After pre-calibration of the pH meter with the value buffers 7.00 and 4.01, the glass electrode was introduced into 100 ml of sample and the values are read on the digital display [14, 16].

The electrical conductivity was evaluated using a HANNA HI 8733 series conductivity meter. The values are expressed in µS/cm.

The colour was measured in nm. A 25 ml volume of sample was placed in a spectrophotometer cell and introduced into the Hach DR 2010 spectrophotometer. The colour reading is taken at λ= 455 nm by reference to the colour of distilled water (Anonymous, 2013).

Nitrate levels were determined by colorimetry with the HACH DR/2000 spectrophotometer, using the Nitraver III.

The reading was taken at 400 nm and the results are expressed as mg/L NO3- [15].

The orthophosphate content of the water was measured colorimetrically with the HACH DR/2000 spectrophotometer using Phosver III. The reading was taken at 890 nm and the results expressed in mg/L of PO43- [15].

The purpose of this test is to evaluate the purification performance of the plant in terms of health, i.e. its capacity to eliminate pathogenic germs. The micro-organisms selected are bioindicators of faecal pollution: faecal coliforms (FC) and faecal streptococci (FS).

Station A1 (3°9245'N, 11°53202'E) is located approximately 9.9 km from the source, at an altitude of 700 m. It is located in the Yaoundé 1 district, in a cultivated area that is becoming a residential area. This station is located 300 m upstream of the confluence of the Ako'o stream with its tributary Bilondo, which is loaded with untreated waste from the Etoudi slaughterhouse (Figure 6). The vegetation is quite abundant and dominated by the species Acroceras zyzanoïdes, Tithonia diversifolius on the right bank and Acroceras zyzanoïdes on the left bank. It should be noted that station A1 is located downstream of the Etoudi district, whose domestic and urban wastewater is discharged into the river without treatment.

Station A2 (3°92912'N, 11°53710'E) is located about 10.5 km from the source, at an altitude of 680 m. It is 300 m downstream of the confluence of the Ako'o and Bilondo rivers and in the same locality as station A2 (Figure 6). It is located 300 m downstream of the confluence of the Ako'o and Bilondo rivers and in the same locality as station A2 (Figure 6). The vegetation is dominated on the right bank by Setaria barbata, Tithonia diversifolius and Echinocloa pyramidalis and on the left bank of the river.

The analysis carried out made it possible to measure the degree of pollution of the wastewater discharged by the Etoudi slaughterhouse. After sampling the wastewater in the different stations, it was collected in a cubical container, homogenised and immediately sampled using clean polyethylene bottles of 1.5 l volume. The collected wastewater was collected and then taken to the laboratory for physicochemical and bacteriological analysis.

3. Results

3.1. Overview of Wastewater Management at the Etoudi Slaughterhouse

The analysis of the survey forms concerning the state of insalubrity made it possible to obtain the opinion of staff and customers on the degree of insalubrity in the Etoudi abattoir. The results obtained show that 39.22% of the staff and users surveyed said the abattoir was less dirty, 28.29% found it dirty, 19.80% found it very dirty, 5.31% considered it clean and 7.38% had no opinion. (Figure 1).

The results of the staff and neighbourhood surveys on the effectiveness of the wastewater management system shows that only 17% of those interviewed thought the wastewater management system was good, 27% thought it was fair and 56% thought it was poor (Figure 2). On the other hand, 27% say it's fair and 56% say it is poor (Figure 2.).

Figure 1. *Sanitary conditions of the Etoudi slaughterhouse.*

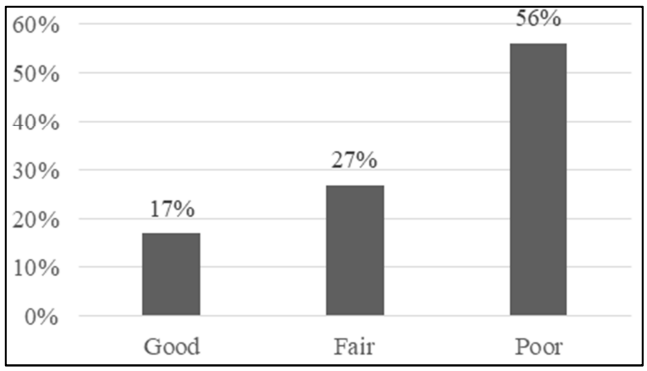

Figure 2. *Assessment of the wastewater management system by the slaughterhouse.*

Figure 3. *Overview of the slaughterhouse WWTP.*

For several years, this treatment plant has been out of service due to regular breakdowns, lack of qualified maintenance staff and the failure to provide an annual budget for its operation. For example, the two sludge motors or aerators have been stolen, the multiple valves are rusty, the compressor is defective, the different compartments are cracked, the sandbox is damaged (Figure 3). The part of the wastewater that arrives at the WWTP escapes untreated into the Ako'o River where it is discharged, causing a serious risk of contamination and pollution. In addition, nauseous odours are persistent in this area.

3.2. Assessment of the Slaughterhouse Wastewater Management

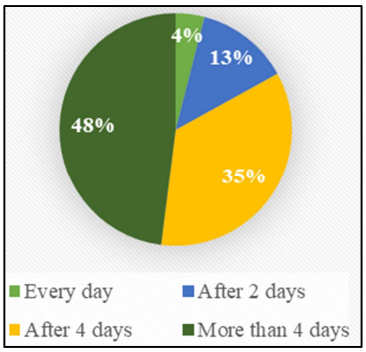

Figure 4. *Time taken to replenish the packaging bins.*

Figure 5. *Liquid waste storage sites.*

Figuree 6. *Liquid waste collection and transport system.*

The figure shows that at the slaughterhouse the conditioning bins are filled much more daily, i.e. 48.8%, 32.6% in 3 days, 10.2% in 2 days and very few who do not know (8.4%) the time required (Figure 4.). The collected waste is stored in a 150 m^3 pit (Figure 5.), which gives off a bad smell and the development of insects. Liquid waste is collected from the slaughterhouses once a week (Figure 6.).

3.3. Characterisation of Physicochemical and Biological Parameters of Wastewater Discharges from the Slaughterhouse

The physicochemical composition of the wastewater discharges shows high pollutant loads after three campaigns (Table 1). These results also show that these waters are very rich in organic, mineral and fine particles. The COD (10,840.5 mg/l) and BOD5 (3,000.4 mg/l) values remain within the range of reference values for wastewater of domestic origin with an average COD/BOD5 ratio of 2.51. The pH is slightly basic. The parameters indicating organic pollution have very high values. Thus, a high electrical conductivity (1220 µS/cm) is observed, which indicates a high level of mineralisation (Table 1). TSS (3,000 mg/L), chlorides (1478 mg/L of Cl-1) and calcium hardness (42,600 mg/L of CaCO3) reach record levels (Table 1).

The values obtained are far above the MINEPDED standard. These results also show that these waters are very rich in organic and mineral substances. The COD and BOD5 values remain within the range of reference values for domestic wastewater with an average COD/BOD5 ratio of 2.51.

In general, the physical and chemical quality of the water sampled at station 1 at station 2 shows pollution of the water body. At first sight, it can be seen that despite dilution, several of these parameters, notably TSS, COD, BOD_5, nitrates and phosphates, have values higher than the considered standards (Table 2).

The results (Table 3) clearly show that coliforms and faecal streptococci are present at high concentrations, 7800 and 4300 CFU/100 ml, respectively (Table 3). The discharge of water loaded with microbes in this way into the environment without any treatment inevitably leads to the contamination of the receiving environment and the spread of waterborne diseases, especially diarrhoea, which is the cause of high infant mortality in Africa.

Table 1. *Physico-chemical characteristics at the outlet of the station in comparison with the standards.*

Parameters	Mean ± standard deviation	Discharge standards	Min - Max
pH	7,4 ± 0,3	6-9	7,07 – 8
Temperature (°C)	28,28 ± 1,8	30	22 - 27
CND (µS/cm)	1220 ± 340,2	/	143 - 538
TSS (mg/l)	3000 ± 111,7	≤ 30	311 - 3930
Colour (Pt-Co)	6736 ± 4428,3	/	955 – 11550
NH_4^+ (mg/l)	1250 ± 121,3	≤ 30	10 – 62,25
NO_3^- (mg/l)	79,65 ± 77,6	/	0 - 190
NO_2^- (mg/l)	900± 77,6	/	35 – 162,25
PO_4^{3-} (mg/l)	164,75 ±136,9	≤ 10	17,5 - 350
Cl- (mg/l)	1478,75 ±126,9	/	855 – 11550
O2 (mg/l)	4285,75 ±226,9	/	324-2145
CaCO3 (mg/l)	42600 ±456,9	/	345-2465
COD (mg/l)	10 840,5 ± 2309,7	≤ 200	849 - 6005
BOD_5 (mg/l)	3000,4 ± 347,8	≤ 100	120 - 960

Table 2. *Average concentration of physico-chemical parameters of wastewater from the Etoudi slaughterhouse.*

Parameters	Concentration station 1	Concentration station 1	Discharge standards
CND (µS/cm)	143,2 ± 10,23	538 ± 83,86	
TSS (mg/l)	111 ± 17,31	19 ± 3,69	
NO_3^- (mg/l)	80 ± 7,65	01 ± 0,29	≤ 30
PO_4^{3-} (mg/l)	80 ± 6,89	01 ± 0,81	≤ 10
NH_4^+ (mg/l)	100,1 ± 21,29	3,8 ± 1,31	≤ 30
COD (mg/l)	2240 ± 209,72	150 ± 32,21	≤ 200
BOD_5 (mg/l)	700 ± 127,79	60 ± 57,85	≤ 50

Table 3. *Average concentration of bacteriological parameters in the wastewater of the Etoudi slaughterhouse.*

Parameters	Fecal coliforms (UFC/ 100 ml)	Fecal Streptococci (UFC/100 ml)	Discharge standards
Station 1	7800	4300	≤ 2000
Station 2	6500	2800	≤ 1000

4. Discussion

The temperature of 24°C is within the range of the thermal averages (21 - 25°C) obtained by Zébazé [9] and Kegne [3]. This value is lower than 30°C, which is considered the limit value for direct discharge of wastewater into the receiving environment. The pH value obtained is comparable to those obtained by several authors on discharges from the Etoudi slaughterhouse and from other slaughterhouses in the world [2, 14, 17]. On the other hand, it is not in agreement with those found by Mbog, 2013 in the wastewater of the university hospital in Yaoundé. The value of electrical conductivity shows an excessive mineralization of the effluent of the slaughterhouse discharges. Indeed, Nyamsi [18], suggest that average values between 449.7 and 1037.3 µS/cm highlight a strong mineralization. Labioui and Onana also found values that show excessive mineralization. Ammoniacal nitrogen levels are very high compared to the values obtained by Zébazé [9].

The BOD5 value is close to those of Adeyemo and Moungang [16, 17] and remains slightly higher than those obtained by Kegne [3]. This value could be explained by the abundance of organic matter in the slaughterhouse discharge. Similarly, the COD value corresponds to the value found by Kegne [3, 6]. The BOD5 and COD values of this study remain high and indicate a high contamination by oxidable matter and particularly organic matter.

Finally, the levels of the different parameters indicating organic pollution in the waste effluent from the slaughterhouse confirm the observations that led to the classification of slaughterhouses among the main industries responsible for organic pollution [6, 11]. However, the results of the analysis of some physico-chemical parameters of the effluent of the slaughterhouse discharges show values extremely higher than the maximum concentrations of the discharges of the main pollutants of the Cameroonian and even French legislation [3]. This indicates a total lack of treatment of the effluent from the Etoudi slaughterhouse.

The temperature of the water in the Ako'o varies very little throughout the period of this study (19.4 - 22.4°C). This can be explained by the fact that thermal seasonality is not very marked in the tropics. The effluent temperature of the slaughterhouse discharge of 24.7°C does not influence the water temperature of station A2. In this respect, E. M. & O. M. Labioui H. et al. [12] points out that the temperature of surface waters is strongly dependent on the ambient temperature. This temperature range is somewhat lower than that obtained by Zébazé [9] which was 23.9 - 25°C and similar to that of Kegne [3].

The highest average levels of TSS, colour and turbidity are recorded at station A2. Kegne [3] and S. Mbog [6] had also obtained the highest levels of these 3 parameters at a station downstream of the discharges. These high levels at station A2 are believed to be the result of the input of effluent from the abattoir. The sudden increase of these 3 parameters at all stations in August could be explained by heavy rainfall that preceded our sampling during that month. The rainfall runoff would result in the transport of a large amount of litter into the watercourse, as well as the permanent discharge of mineral and organic particles carried by the water.

The high CO_2 values recorded could be the reason for the acidic pH trend. This could be explained by a low photosynthetic activity of the aquatic flora. The low levels of alkalinity recorded corroborate the acidic trend of the waters of the Ako'o and Yaoundé region.

Due to the exogenous origin of PO43-, the high orthophosphate values recorded during this study at station A2 would show the effect of the impact of the effluent of the slaughterhouse discharges in the Ako'o stream. This observation was also made by Mbog [6].

The high concentrations of ammonia nitrogen, nitrates and nitrites obtained during the months of July and August at stations A1 and A2 show the influence of the effluent of the slaughterhouse discharges in the concentration of these parameters. Labioui, who did not measure nitrate and nitrite levels, also observed that the effluent from the slaughterhouse increased the ammonia ion content of the environment [12].

The results obtained show that the waste effluent from the slaughterhouse would not have a direct impact on the electrical conductivity of the Ako'o waters. This can be explained by the high TSS load and the very high turbidity, which reduces the solubility capacity of the Ako'o waters.

In general, the effluent from the slaughterhouse, rich in

organic matter, is an important source of organic pollution in the Ako'o. This strong pollution, especially observed upstream of the confluence of the watercourse with the effluent from the slaughterhouse, would be due to the effluent from the slaughterhouse, even if it is necessary to take into account the domestic discharges that are quite abundant along the Ako'o. The majority of the physico-chemical parameters are very high at the A2 stations compared to the other stations, confirming the results of Zébazé, Kegne and Mbog according to which the effluent of the slaughterhouse discharges have a negative impact on the physico-chemical quality of the Ako'o river [3, 6, 9].

5. Conclusion

This study aimed to show the impact of wastewater discharges from the Etoudi slaughterhouse on the environment in the Santa district. The analysis of wastewater from the Etoudi slaughterhouse shows high levels of the main physico-chemical parameters indicating organic pollution, which significantly exceed the limit values for direct and indirect discharge into the receiving environment. This constitutes an important source of pollution of the environment in general and of the Ako'o river in particular. The wastewater discharged in this way is rich in organic pollutants (BOD5 = 3000 mg/l) and (COD = 10,830 mg/l on average), in suspended solids (SS = 3000 mg/l on average), in nutrients (PO_4^{3-}= 127 mg/l and $N03^-$= 70 mg/l on average). They also contain dangerous chemical substances (heavy metals, metal salts, acids, dyes), pathogenic and non-pathogenic micro-organisms, some of which are indicators of pollution (faecal streptococci > 3000 CFU/100 ml, faecal coliforms > 7000 CFU/100 ml). In view of the harmful effects of these effluents on the environment and on humans (toxicity, eutrophication, contamination of receiving ponds, contamination and pollution of groundwater, propagation of water-borne diseases), they should be treated before discharge. On the other hand, the risks linked to these discharges from the slaughterhouse are obvious on the health of the population, which could have numerous bacterial and viral infections.

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