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Assessment of the impact and causes of malfunction of the wastewater treatment plant of CRE (Cameroon Real Estate Company) camp of the "Cité-Verte" district (Yaoundé Cameroon)

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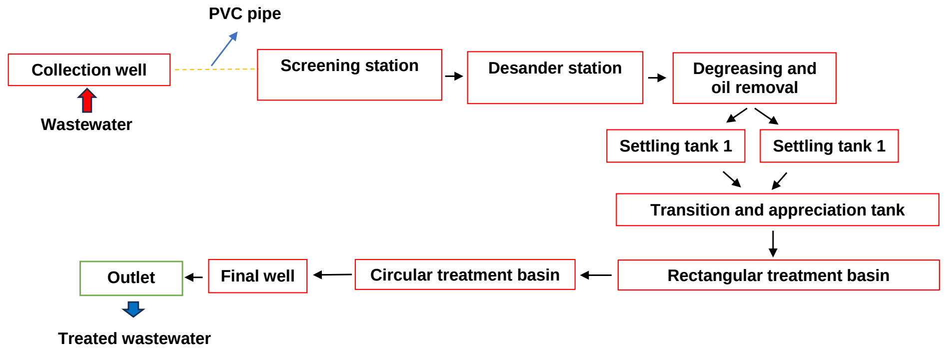
GRAPHICAL ABSTRACT

Synoptic diagrams of the wastewater treatment steps in the WWTP



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ABSTRACT

This paper assesses the environmental impact of the wastewater treatment plant (WWTP) of the Cameroon Real Estate Company (CRE) camp in the "Cité-Verte" district in Yaoundé (Cameroon) and the causes of its malfunction. The study was carried out in two stages. The first stage consisted of describing the wastewater treatment steps of the WWTP, and analyzing the staff interviews in order to determine the causes of malfunction that had been suspected. The second phase consisted of collecting water samples at the entry of the WWTP (P1), inside the WWTP (P2), and at the outlet of the WWTP (P3). This, in order to produce a list of the WWTP's collecting systems, characterize the various types of wastewater (P1 and P2) and the treated wastewater (P3), and then determine the effect of effluent discharges on the environment. Finally, the structural and operational malfunctions of WWTP are identified using the Ishikawa and the Pareto diagrams. The results of water characterization show that the mean values of pH (7.7), EC (1059.3 µS/cm), TDS (524.6 mg/L), T° (23.6 °C), BOD_5 (10.8 mg/LO2), NO_3^- (2.3 mg/L), and fecal coliforms (447.3 CFU/100 mL) are below the acceptable limit values of the Cameroonian standard of treated wastewater discharge. However, the mean values of TSS (269.3 mg/L), PO_4^{3-} (1661.6 mg/L), K^+ (1220.6 mg/L) and Escherichia coli (10133.3 CFU/100 mL) exceed the recommended values set by the Cameroonian standard of treated wastewater discharge. The values of the wastewater parameters at the sampling point P3 are globally lower than those at the sampling point P1 but higher than Cameroon's standard for PO_4^{3-} and K^+. These results demonstrated that the current system (filters and plants) is appropriate but not optimal. The Pareto diagram reveals that the inadequate plant controls, unfavorable working conditions, lack of maintenance and systematic control, and outdated equipment represent 20% of the causes responsible for 80% of the WWTP's malfunction. Therefore, the implementation of corrective and preventive measures is essential for better monitoring and determinization of the optimal performance of the WWTP of the CRE camp in the "Cité-Verte".

1. Introduction

Environmental problems have globally received more attention in recent years and efforts have been made to reduce these problems. The sustainable management of wastewater is a global challenge for the 21st century. Such management must be based on a global vision of the challenges of the urban water management system. Succeeding in this task requires a global approach to issues involving the water

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cycle. Indeed, one of the main difficulties lies in the fragmented nature of decisions relating to the management of this resource (WWC, 2000). In order to preserve the environment and water resources, wastewater must undergo biological and physico-chemical treatments before being discharged into nature. These treatments are carried out in polluted water treatment plants. Wastewater is used for domestic, industrial or agricultural purposes, therefore constituting polluted effluents that are discharged into a sewer network. They include domestic water (black water and gray water), runoff water and industrial effluents (Baumont et al., 2004).

Several authors have evaluated the impact of wastewater treatment plants on the environment around the world. Mohammad et al., (2015) studied the environmental impacts of Al-Hilla City Wastewater Treatment Plants. Al-Dosaryet al., (2015) assessed the environmental impacts of two wastewater treatment plants (WWTP), located in Cairo, and assessed the influence of WWTP design capacity on the overall damage of the environmental. Zhao et al., (2015) assessed the environmental impact analysis of wastewater treatment process based on life cycle assessment. Bonetta et al., (2022) evaluated the impact of wastewater treatment plants on microbiological contamination for evaluating the risks of wastewater reuse. Jaskulak et al., (2022) studied the effects of wastewater treatment plant failure on the Gulf of Gdansk (Southern Baltic Sea). All these studies have shown that WWTP can have negative impacts on the environment which is worsened if there are malfunctions involved. It therefore seems essential that these WWTP operate optimally with the possibility of reusing the treated wastewater.

The watercourses of the Mfoundi watershed are subject to anthropogenic organic pollution which is the result of their use for the evacuation of waste from the city of Yaoundé and its surroundings. Thus, these watercourses receive waste effluent from the WWTP of the CRE camp of the “Cité-Verte” district. This WWTP treats the water used for washing by-products, eliminating waste and other debris that are loaded with organic matter, which could become major sources of pollution for the receiving environment. In addition, the daily discharge of these effluents into nature implies that their pollutant content is reduced, in order to reduce the negative impact on the environment and biodiversity. In Cameroon, the discharge of industrial and domestic effluents is strictly regulated and controlled by Law No. 96/12 of August 5, 1996 on the framework law relating to environmental management, specifically Chapters I and III; there is also Law No. 98/005 of April 14, 1998 on the water regime.

In most African countries, the problem of sanitation in general and that of wastewater in particular are still not a priority. This situation is certainly one of the causes of the high prevalence of waterborne diseases observed in these countries. Untreated wastewater is a breeding ground for the development of many disease vectors, including malaria, which is endemic in most African countries. The volume of uncontrolled wastewater discharge increases with the population density and industrial development. These discharges are drained towards a natural aquatic outlet which cannot absorb the massive flow of pollution (Ayo, 2012). The work of Wethe, Radoux and Tanawa (2003) showed that in the city of Yaoundé, like most cities in Cameroon, wastewater is generally discharged into the natural environment without prior treatment due to the dilapidated state of the installations and the malfunctioning of most WWTP when they exist. In order to reverse the trend, the Yaounde City Council has considered the rehabilitation/renovation of the various WWTP in the city of Yaounde, in this case that of the “Cité-Verte” district. Thus, a hybrid system-type wastewater treatment plant using planted filters was built downstream of the waste water collection system of the WWTP of CRE camp of the “Cité-Verte” district. However, the provision of this instrument for the preservation of the environment requires permanent monitoring in order to guarantee the purifying performance envisaged. Since this task is the poor relation of the activities of most of our institutions, it seems important to know the level of treatment performance of this WWTP and, in the event of malfunction, the potential causes and effects.

The aim of this study is to assess the impacts on the environment and the causes of malfunction of the WWTP of CRE camp of the “Cité-Verte” district at Yaoundé (Cameroon). Therefore, the objectives are to: make an inventory of the collection works and the treatment plant; (ii) characterize the wastewater (P1 and P2) and the treated wastewater (P3) and assess the impacts of effluent discharges on the natural environment; (iii) analyze the causes of the wastewater treatment plant's malfunction using the Ishikawa and Pareto diagrams; and (iv) propose corrective and preventive measures to reduce the negative impacts on the natural environment and to remedy the malfunction of the WWTP.

2.1. Description of the wastewater treatment process of the CRE Camp of the “Cité-Verte”

The WWTP of the CRE camp of the “Cité-Verte” is a station that treats wastewater including a hybrid system, filters and plants. The four steps of the treatment are as follows: (i) the network for collecting wastewater; (ii) pre and primary treatment; (iii) secondary (biological) treatment; and (iv) release into the environment.

The role of the wastewater collection network is to collect wastewater from WWTP of the CRE camp of the “Cité-Verte for treatment. All of the wastewater entering the WWTP enters at the network which separately collects rainwater and domestic water. It enables better flow and pollution concentration management as well as better capacity adaptation for the wastewater treatment facility at the CRE camp. The network used to collect wastewater is unique. Hence, it is made up of: (i) a collection of primary sewer/manhole shapes that enable wastewater to be collected from homes and dumped into a public sewer and (ii) a set of collectors/intermediate manholes that accept waste water that also comes from private collectors.

Preparing wastewater for further treatment is the goal of pretreatment or primary treatment. This is done to get rid of substances that can obstruct further purification in the rest of the WWTP. It consists of two parts: (i) a screen to catch coarse materials that are likely to wind up in the wastewater, and (ii) a desander to get rid of suspended solids. (iii) a degreaser/oil remover to remove fats and oils through the flotation process. These particles can harm or clog pipes. Skimming the surface removes these fats and oils, which can then be used, for instance, to make biogas; (iv) settling tanks are used to collect the streams of sludge produced by the degreaser/oil remover (caused by the outlet water). This prevents the biological basin from becoming overloaded with sludge, which would increase the water's turbidity, and (v) a transition and appreciation tank to monitor the effectiveness of the pre-treatment. Whenever water from primary treatment is being analyzed, it also functions as a sampling location. A transition tank between primary and secondary (biological) treatment is also provided by it.

A hybrid system, filters, and plants are used for secondary treatment. The filter/plant basin, which consists of an artificial tank filled with water, substrate, and vascular plants receives wastewater. The substrate is made up of stones, gravel, and sand (ballast). These materials' permeability will be used to keep the waste and sediment in the treated water in place. Pollutants like metals and nitrogen can be removed since the saturation of the substrate renders it anaerobic.

The effluent is evacuated and directed through PolyVinyl Chloride (PVC) pipes to the receiver after treatment. The Abiergue watercourse, a tributary of the Mfoundi River, serves as the receiving system.

2.2. Sampling and analytical procedures

2.2.1. Sampling of waters

The water samples were taken on July 24, 2021 according to the standard protocol (ALPHA, 2005). Polyethylene bottles with double caps measuring 250 and 1000 mL were used to collect water samples. P1 corresponded to the sample obtained at the WWTP's entry at the level of the screen, P2 for the sample taken inside the WWTP, and P3 for the sample taken at the WWTP's outlet. It is regarded as effluent that has been treated. Before sampling, the effluent and treated wastewater were stirred up quickly to ensure that the medium was very homogeneous. The instrument, which had been cleaned with distilled water beforehand, was dropped right into the basin. The conservation of the samples after collection was done in coolers lined with ice cubes and then transported to the laboratory for further analyses.

2.2.2. Analyses of physico-chemical, chemical and bacteriological parameters of waters

The physico-chemical parameters analyzed in the wastewater and treated wastewater samples were pH, total dissolved solids (TDS), electrical conductivity (EC), temperature (T°), total suspended solids (TSS), and biological oxygen demand (BOD). A HANA model HI multi-parameter 9829 was used to determine the pH, electrical conductivity, TDS, and T°, which were expressed in UC, S/cm, mg/L, and °C, respectively. A DR/3900 spectrophotometer was used to perform colorimetry in order to measure the total amount of suspended solids (TSS) at wavelengths of 810 nm. The BOD; expressed in mg/L of O_2 was measured by respirometry using a Liebherr brand BOD incubator, at 20°C and in the dark for 5 days.

The chemical parameters determined in the wastewater and treated wastewater samples were nitrates (NO_3^-), phosphates (PO_4^{3-}) and potassium (K^+). The analysis was done by colorimetry, with the DR/3900 spectrophotometer.

The bacteriological parameters analyzed in the wastewater and treated wastewater samples were fecal coliforms (CF) and Escherichia coli (Ec). The bacteriological analysis was carried out immediately, upon arrival at the laboratory. The direct counting of the colonies resulting from the germs contained in the test sample after inoculation on solid culture medium was used as a method of analysis. The different steps of the membrane filtration technique used are detailed below. The sample was diluted if necessary using sterile physiological water. The method of analysis by “colimetry on filter membrane” was used. After filtration of the water samples, the membrane was placed on an appropriate support (agar or absorbent pad saturated with nutrient medium). Bacteria colonies will develop preferentially during an incubation of 18 to 24 hours at a temperature of 44 ± 0.5°C for fecal coliforms, or at 37 ± 0.5°C for germs. An appropriate volume of water sample in general 10^{-5} to 10^{-3} mL in order to form at most 80 colonies per membrane. Vacuum filtration under sterile conditions was applied. This filtration was done after adding a certain amount of dilution and homogenization water. Each membrane is then placed in a petri dish; lactose agar poured on it with TTC and tergitol 7 and incubated for 24 hours. The physico-chemical, chemical and bacteriological analyses were carried out in the Microbiology laboratory of the Faculty of Sciences of the University of Yaoundé I (Cameroon).

2.3. Identification of the causes of malfunctioning of the treatment plant

The Ishikawa or 5M technique and the Pareto diagrams were used as analytical tools to determine the causes of the WWTP's malfunction.

2.3.1. Ishikawa diagram

Also called fishbone diagram, or cause and effect diagram, it was invented by Professor Kaoru Ishikawa in 1943. This diagram is an analytical tool that reveals the root causes of a problem. It is a tool for distributing and classifying the identified causes of an effect to be treated. The name "5 M" comes from the initial of each family name used: Workforce, Material, Methods, Environment and Raw material. This method leads to a common and non-hierarchical vision of the causes generating the observed effect. To construct the “Fishbone” diagram, we list all the causes that could be the source of the problem. All these causes mentioned above will then be grouped by family (Goetsch and Davis, 2003). The representation of the Ishikawa diagram is shown in Fig. 1.

2.3.2. Pareto diagram

The purpose of the Pareto diagram is to detect the exact causes on which the wastewater treatment plant will have to act the most to reduce the defects as considerably as possible. The importance of each of these causes and their flaws will be ranked in descending order. After that, a diagram will be created to clearly demonstrate which reasons should be given priority over others in a given order. In fact, Pareto is a graphic tool for categorizing data. According to Pareto's law, sometimes known as the 80/20 rule, 80 % of effects result from 20 % of causes. In rare circumstances, we can get close to the ratios of 75% to 25% or even 60 % to 40 %. It will therefore be necessary to focus on these 20 %, 25 or 40 % respectively to obtain satisfactory results. The Pareto diagram is therefore an effective decision-making tool, which allows resources to be devoted to the essential causes that have a major impact (Goetsch and Davis, 2003).

An analysis of the malfunction of the WWTP of CRE camp of the “Cité-Verte” district network will have a considerable impact on the treatment plant and the inhabitants. This was done based on the survey of the employees of the WWTP. These employees (30) were qualitatively surveyed to build the diagram and identify the primary causes. A total of 205 reviews were gathered. The Pareto diagram would be the ideal way to display the rate of the causes that produce the greatest number of effects on the basis of this analysis.

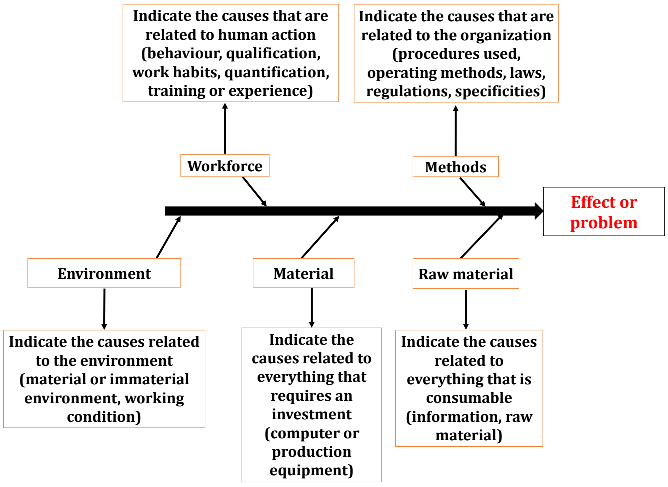

Fig. 1. Illustration of Ishikawa diagram.

3. Results and discussion

3.1. Physico-chemical, chemical and bacteriological characteristics of wastewater and treated wastewater

Table 1 presents the descriptive statistical analysis of the parameters analyzed in wastewater and treated wastewater samples and the comparison of the obtained values with the Cameroonian standard of treated wastewater discharge.

3.1.1. Physico-chemical characteristics of wastewater and treated wastewater

The variation of the studied physico-chemical parameters in the sampling points P1, P2 and P3 is shown in Fig.2.

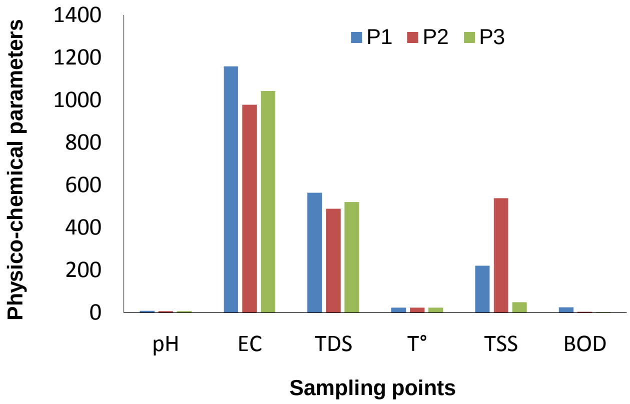

Fig. 2. Variation of physico-chemical parameters in the sampling points P1, P2 and P3.

Table 1. Descriptive statistics of wastewater and treated wastewater parameters and the comparison with the Cameroonian standard of treated wastewater discharge.

Parameters	Minimum	Mean	Maximum	SD	CV (%)	Cameroonian standard
pH	7.35	7.7	8.44	0.57	7.34	6 - 9
EC, µS/cm	978	1059.3	1158	91.24	8.61	-
TDS, mg/L	489	524.6	564	37.63	7.17	300 – 600
T, °C	23.4	23.6	24	0.35	1.47	< 30
TSS, mg/L	49	269.3	538	248.1	92.1	40
BOD_5, mg/LO_2	2.31	10.8	25.4	12.66	116.6	50
NO_3^-, mg/L	2.08	2.3	2.51	0.22	9.59	20
PO_4^{3-}, mg/L	394	1661.6	2653	1155	69.48	10
K^+, mg/L	852	1220.6	1523	340.4	27.88	50
FC, CFU/100 mL	124	447.3	1030	505.6	113.03	2000
Ec, CFU/100 mL	2300	10133	16600	7247	71.53	1000

Key: SD = standard deviation and CV = coefficient of variation.

With a mean of 7.7, the pH ranged from 7.35 to 8.44. The water samples P2 and P3 had pH values that fell within the range (6-9) as prescribed by the Cameroonian standard of treated wastewater discharge (Table 1). The EC values ranged from 978 to 1158 S/cm, with a mean value of 1059.3 S/cm. The EC describes the water's capacity to conduct electricity. The TDS values ranged from 498 to 564 mg/L, with a mean of 524.6 mg/L. The TDS value was higher at the entrance of the WWTP (P1) than the outlet of the WWTP (P3) (Fig. 2). This demonstrated the significant decrease of TDS in the WWTP. The TDS concentrations were below the Cameroonian standard of treated wastewater discharge. Thus, TDS values did not indicate a potential issue with the receiving medium's saturation.

The T° of water sampling ranged from 23.4 to 24 °C, with a mean temperature of 23.6 °C (Table 1). The effluent's T° value at P3 (23.6 °C) was in conformity with the treated wastewater discharge limit value (30 °C), which posed no threat to life in the receiving environment.

The TSS concentrations ranged from 49 to 538 mg/L, with a mean concentration of 269.3 mg/L. The sampling point P2 recorded the greatest concentration (Fig. 2). TSS values were higher than the Cameroonian standard of treated wastewater discharge which recommends a limit value of 40 mg/L (Table 1). TSS values were therefore not ideal for the receiving environment and showed a failure of the WWTP.

The BOD values ranged from 2.31 to 25.4 mg/LO_2 with a mean value of 10.8 mg/LO_2. They highest value was found at P1 (Fig. 2). BOD values were below the minimum value of 50 mg/LO_2 recommended by the Cameroonian standard of treated wastewater discharge (Table 1). The BOD therefore had no negative impact on the receiving environment.

3.1.2. Chemical characteristics of wastewater and treated wastewater

The variation of concentrations of the studied chemical parameters in the sampling points P1, P2 and P3 is shown in Fig. 3.

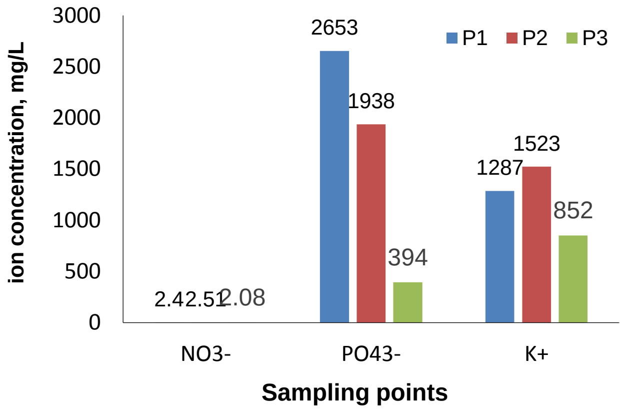

Fig. 3. Variation of the concentrations of chemical parameters in the sampling points P1, P2 and P3.

The concentrations of NO_3^- ranged from 2.08 to 2.51 mg/L, with a mean concentration of 2.3 mg/L. NO_3^- concentrations were below the lowest value of 20 mg/L set by the Cameroonian standard of treated wastewater discharge (Table 1). High doses of nitrates can have negative impacts on human health and animal and plant species.

The concentrations of PO_4^{3-} ranged from 394 to 2653 mg/L, with a mean concentration of 1661.6 mg/L. The concentrations of PO_4^{3-} decreased from the inlet to outlet of the WWTP. They were above the limit of 10 mg/L set by the Cameroonian standard of treated wastewater discharge (Table 1). The high concentrations of PO_4^{3-} likely come from fertilizers used for agricultural work. In addition, the significant reduction in PO_4^{3-} (2653 to 394 mg/L) is due to the adsorption of PO_4^{3-} ions by the substrate during its saturation (Prato et al., 2022). This elimination takes place during the secondary treatment phase. The Phoredox process could also be used for their elimination. High concentrations in PO_4^{3-} are dangerous for the natural environment.

The concentrations of K^+ ranged from 852 to 1523 mg/L, with a mean concentration of 1220.6 mg/L (Table 1). These concentrations exceeded the maximum allowed value of 50 mg/L set by the Cameroonian standard of treated wastewater discharge. K^+ is an important component of the nervous system. Such high concentrations of potassium are very dangerous for the receiving environment. The elimination of K^+ in this water could be done using the activated carbon adsorption technique or natural materials such as clays.

3.1.3. Bacteriological characteristics of wastewater and treated wastewater

The variation of the values of the studied bacteriological parameters in the sampling points P1, P2 and P3 is shown in Fig. 4. The FC values ranged from 124 to 1030 CFU/100mL, with a mean concentration of 447.3 CFU/100mL (Table 1). The fecal coliform values were below the minimum value of 2000 CFU/100mL set by the Cameroonian standard of treated wastewater discharge (Table 1). FC values decreased from the entrance to the outlet of the WWTP, demonstrating the effectiveness of the secondary treatment done by filters and plants.

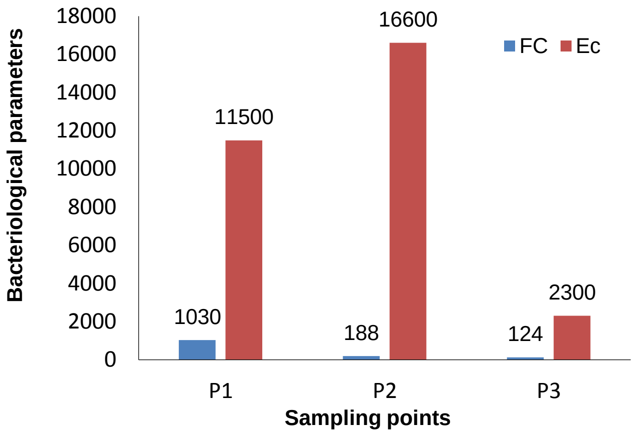

Fig. 4. Variation of the values of bacteriological parameters (FC and Ec) in the sampling points P1, P2 and P3.

The Ec values ranged from 2300 to 16600 CFU/100mL, with a mean value of 10133.3 CFU/100mL. The values of Ec at points P1 and P2 were higher than the maximum recommended value of 1000 CFU/100mL as prescribed by the Cameroonian standard of treated wastewater discharge (Table 1). The value at point P3 at the outlet of the WWTP was lower than the recommended limit of Cameroonian standard of treated wastewater discharge. This shows the performance of the WWTP in the elimination of Escherichia Coli. Escherichia Coli are responsible for diseases like the cholera vibrio vector of cholera, typhoid fever, bacillary dysentery, diarrhea and gastroenteritis, hepatitis A and E, amoebic dysentery. The presence of Escherichia Coli in these waters was of human origin and indicated signs of fecal contamination.

3.1.4. Evolution of wastewater treatment plant performance

In this study, the purifying performance of the WWTP was assessed. This consisted of calculating the percentage of treatment and comparing the results of samples taken at the inlet and outlet of the WWTP (Table 2). Table 2 presents the assessment of the performance of the WWTP between the wastewater collected at the inlet (P1) and the treated wastewater (P3). The purification capacity was high for BOD_5 (90.91 %), FC (87.96 %), PO_4^{3-}(85.15 %), Ec (80 %) and TSS (77.83 %). The purification capacity was low and below 50% for K^+ (33.80%), NO_3^-(13.33%), pH (12.91 %), EC (10.02 %), TDS (7.62 %) and T° (2.50 %). The results obtained at the outlet of the WWTP were in conformity with the values set by the Cameroonian standard of treated wastewater discharge, despite the fact that the purification capacity was not high for these parameters. The purification performance was high for bacteriological criteria (Echinochloapyramidalis) due to the reductions from macrophyte purifying plants. The purification capacity of PO_4^{3-} and K^+ decreased between P1 and P3 (Tables 1 and 2). Nevertheless, it was higher for PO_4^{3-} which leads to the conclusion that these two elements improved the purifying performance of the WWTP's bio-filters. Phosphate is crucial for plant growth and development, it plays a part in plant metabolism. On the other hand, potassium plays such a significant role for the plant since it makes the plant's cell walls stronger, expands the leaf's surface area and chlorophyll content, all of which help to boost the canopy's photosynthesis and the crop's growth. As a result, its two components' contribution to maintaining the macrophyte was almost crucial. In Fig. 5, the causes were distributed according to the 5 M (Workforce, Material, Methods, Environment and Raw material). The raw material to be treated was wastewater, sometimes containing sludge, suspended solids or oils. According to the method, the causes were linked to the techniques of pre-treatment, primary treatment (screen, desander, oil removal and setting) and secondary treatment using filters and plants. The obsolete nature of the equipment, the lack of systematic maintenance and regular checks, the lack of equipment had direct negative impacts on treatment techniques. Added to this, the frequent absences of staff, their lack of required skills and their limited number and finally the quality of the checks on the installations. These shortcomings coupled; with a poor working environment had impacts on the environment, in particular the unhealthy connection of the installations of the WWTP to the habitats causing regular leaks, the unsanitary conditions of the wastewater treatment plant and the discharge of poorly treated water in the environment.

Table 2. Assessment of the purification performance of the WWTP.

Parameters	P1	P3	Purification capacity, %	Cameroonian standard
pH	8.44	7.35	12.91	6 - 9
EC, µS/cm	1158	1042	10.02	-
TDS, mg/L	564	521	7.62	300 – 600
T, °C	24	23.4	2.5	< 30
TSS, mg/L	221	49	77.83	40
BOD_5, mg/LO_2	25.4	2.31	90.91	50
NO_3^-, mg/L	2.4	2.08	13.33	20
PO_4^{3-}, mg/L	2653	394	85.15	10
K^+, mg/L	1287	852	33.8	50
FC, CFU/100mL	1030	124	87.96	2000
Ec, CFU/100mL	11500	2300	80	1000

3.2.2. Prioritization of causes by the Pareto diagram

After identifying the causes that contributed to the WWTP's malfunction, it was important to highlight those that had the biggest influence on it. To create the diagram and to identify the main causes of WWTP's malfunction, qualitative surveys were conducted on the WWTP employees (30). 205 reviews were gathered from employees. The results are presented in Table 3. The results of the Pareto diagram are presented in Fig. 6.

Table 3. Causes of the malfunction of WWTP, results of surveys, percentage based on total survey notices and cumulative percentage.

Causes of malfunction of the WWTP	Staff reviews	Percentage (%)	Cumulative percentage (%)
Pre-treatment	4	1.95	1.95
Primary treatment	3	1.46	3.41
Secondary treatment	10	4.88	8.29
Unqualified staff	6	2.93	11.22
Insufficient staff	11	5.36	16.58
Frequent absence of staff	13	6.34	22.93
Quality of control	20	9.76	32.68
Bad working conditions	23	11.22	43.90
Bad connection of the station to homes	12	5.85	49.76
Camp's poor sanitary conditions	16	7.80	57.56
Discharge into natural environment	11	5.36	62.93
Wastewater	8	3.90	66.83
Absence of systematic maintenance and control	24	11.71	78.54
Incomplete equipment	19	9.27	87.80
Obsolete equipment	25	12.19	100
Total number of reviews	205		

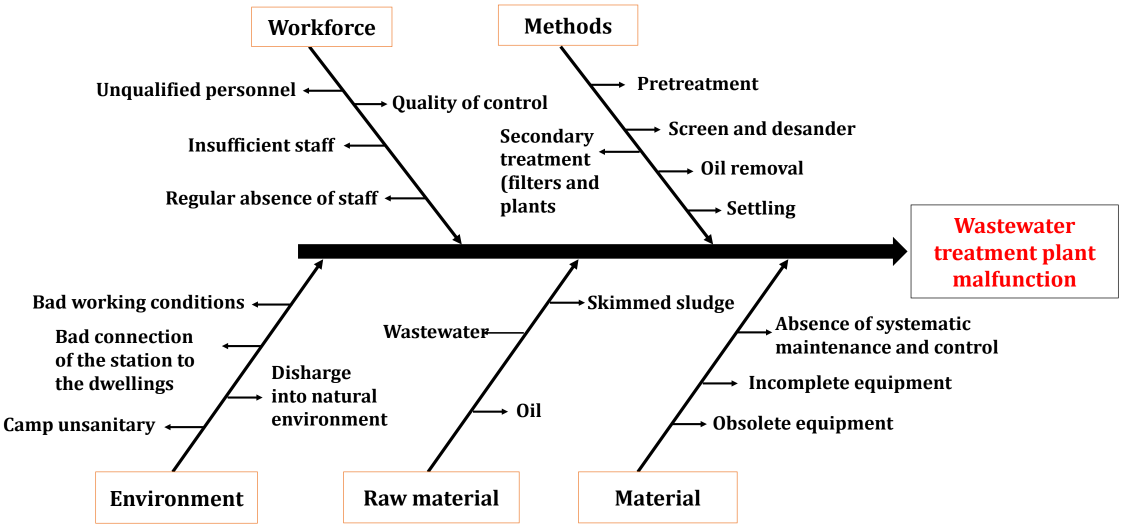

Fig. 5. Causes of wastewater treatment malfunction using Ishikawa diagram.

According to the Pareto diagram (Fig. 6), the inadequate plant controls, unfavorable working conditions, lack of maintenance and systematic control, and outdated equipment represented 20% of the causes which were responsible for 80% of the WWTP's malfunction. As a result, it seems crucial to pay utmost attention to these causes in order to address 80% of the issues relating to the malfunction of the WWTP of the CRE camp of the "Cité-Verte" in Yaoundé. To obtain optimum performance from the WWTP and to reduce the impact on the natural environment, some solutions should be implemented. These solutions are to: (i) improve the working conditions of staff (salaries, working equipment); (ii) perform systematic follow up and maintenance of equipment; (iii) perform systemic control and monitoring of facilities; (iv) acquire new processing equipment; (v) use depollution process techniques such as the Phoredox process for the elimination of phosphate and adsorption for the elimination of phosphate, potassium and heavy metals; (vi) establish sanitation, danger, risk and environmental impact plans.

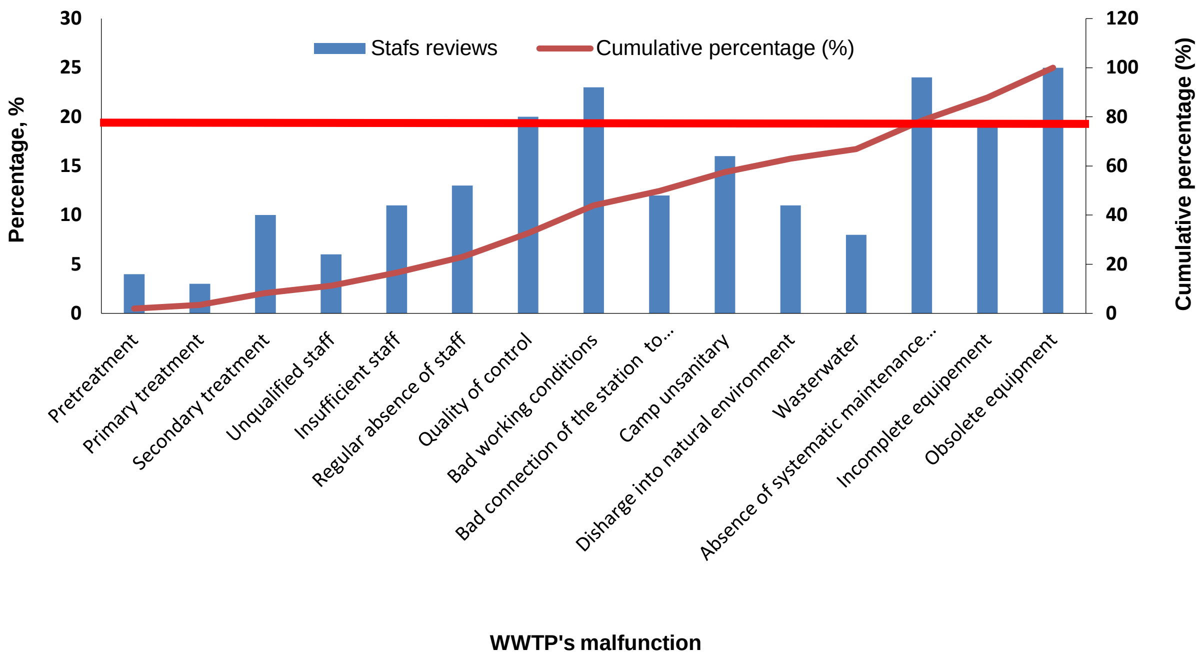

Fig. 6. Pareto diagram showing the main causes of WWTP's malfunction (the red bar representing the 80/20 law).

4. Conclusions

This paper assessed the impact on the environment and the causes of malfunction of the wastewater treatment plant (WWTP) of Cameroon Real Estate Company (CRE) camp of the "Cité-Verte" district at Yaounde (Cameroon). The study consisted of collecting and characterizing the wastewater and treated wastewater samples at the inlet, inside and outlet of the WWTP in order to determine its purifying performance. The probable causes of the malfunction of the WWTP were identified using Ishikawa and Pareto diagrams. The results of water characterization showed that the mean values of the studied physico-chemical parameters, in particular pH (7.7), EC (1059.3 µS/cm), TDS (524.6 mg/L), T° (23.6 °C), BOD_5 (10.8 mg/LO_2), NO_3^- (2.3 mg/L) and fecal coliforms (447.3 CFU/100 mL) were lower than the permissible boundary values of the Cameroonian standard of treated wastewater discharge. The mean values of TSS (269.3 mg/L), PO_4^{3-} (1661.6 mg/L), K^+ (1220.6 mg/L) and Escherichia coli (10133.3 CFU/100 mL) were higher than the extreme values prescribed by the Cameroonian standard of treated wastewater discharge. The Pareto diagram revealed that the inadequate plant controls, unfavorable working conditions, lack of maintenance and systematic control, and outdated equipment represent 20% of the causes responsible for 80% of the WWTP's malfunction. To remedy the negative impacts of the WWTP on the environment and its malfunction, the improvement of working conditions, the systematic follow up and maintenance of equipment, and the systemic monitoring of installations will make it possible to obtain optimal performance of the WWTP. For future works, it would be interesting to increase the sample size and to carry out monitoring over a longer period.

Author Contributions

Mouhamed Ngounouno Ayiwouo and Félicité Obono Mba: Collected the data; contributed data or analysis tools.
Colins Leprince Kombou and Jules Metsebo: Performed the analysis.
All authors have incorporated in writing the paper.

Conflict of Interest

The authors declare no conflict of interest.

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Data Availability Statement

Data will be made available on request.

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