

# Evaluation of Treatment Performance of Kossodo Wastewater Treatment Plant: Microbiological and Physicochemical Parameters

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## ABSTRACT

Burkina Faso is a Sahelian country that naturally faces water resource problems. Wastewater management is a major concern in large cities. The objective of this study was to evaluate the purification quality of the physicochemical and microbiological parameters of wastewater from the Kossodo wastewater treatment plant (WWTP). A total of twenty wastewater samples were taken at the inlet and outlet of the WWTP for analysis. These samples were subjected to physicochemical and microbiological analyses using standard methods. The purification efficiencies for thermotolerant coliforms, *Escherichia coli*, fecal streptococci, *Salmonella*, coliphages, and *Pseudomonas* were 99.43%, 57.86%, 86.65%, 99.65%, 96.06%, and 90.42%, respectively. The purification yields for parameters such as pH, TSS (Total Suspended Solids), COD (Chemical Oxygen Demand), and BOD (Biological Oxygen Demand) were 18%, 4.59%, 46%, and 14%, respectively. However, an increase in the load of  $PO_4^{3-}$ ,  $NH_4^+$ ,  $SO_4^{2-}$  et  $NO_3^-$  was observed. The sanitary quality of all samples at the outlet was unsatisfactory. The microbiological parameters show good reduction, but the microbial loads at the outlet do not comply with the standards for treated wastewater discharges. However, physicochemical parameters comply with Burkinabe standards

for wastewater discharges. This work could contribute to better decision-making on the control and optimization of the treatments carried out.

**Keywords:** Wastewater, Treatment performance, Microbiological parameters, Physicochemical parameters, Kossodo WWTP.

## 1. INTRODUCTION

Sustainable water resource management is now a priority for all stakeholders in the water sector, given the vulnerability of drinking water sources and their importance in meeting human needs. According to UNEP [1], the report on global resource prospects, the exploitation of water resources by agriculture, industry, and municipalities has increased dramatically in recent decades, threatening to cause water stress in certain parts of the world. In a Sahelian country such as Burkina Faso, the preservation of water resources is a key factor that is at the heart of several meetings to define national plans and programs [2]. The National Wastewater and Excreta Sanitation Program (PN-AEUE) for 2030 is a program set up for wastewater sanitation with a view to sustainable development [3].

Thus, the recognition of the need to better manage wastewater and excreta has led to the construction and operation of numerous public and private wastewater treatment plants in Burkina Faso, designed to treat domestic and industrial wastewater [4-5]. One example is the Kossodo microphyte lagooning wastewater treatment plant. This plant collects wastewater from industries, the Kossodo slaughterhouse, as well as hospital wastewater from Yalgado and a few homes around Ouagadougou. These effluents are treated naturally and then discharged into the environment or reused in urban agriculture and for watering green spaces [6]. These efforts, together with the construction of wastewater treatment plants, are primarily aimed at mitigating the impact of urban discharges by reducing the flow of pollutants that can pose a

threat to public health and the environment [7-9]. In addition, given the risks that may arise from the reuse of treated wastewater in the event of non-compliance with standards, it is necessary to assess the purification quality of the water to verify that it complies with reuse standards. The overall objective of this study was to assess the treatment quality of the physical, chemical, and microbiological parameters of the wastewater discharged in relation to the discharge standards of the wastewater WWTP in the Kossodo industrial zone located in Ouagadougou.

## 2. MATERIALS AND METHODS

### 2.1. Sites of Study

The study was conducted at the WWTP in the Kossodo industrial zone (STEP). The WWTP was built in 2003 and commissioned in 2004, covering a total area of 10 ha. It receives a large proportion of the domestic wastewater from the city of Ouagadougou, local industries, and the Yalgado Ouédraogo University Hospital. Each basin at the plant has a total volume of approximately 180,000 m<sup>3</sup>. Microbiological analyses were carried out at the Laboratory of Biochemistry and Applied Immunology in the University Joseph KI-ZERBO, and physicochemical manipulations were carried out at ZIE Laboratory and the Laboratory of Environmental Quality Analysis of the Ministry of Environment.

### 2.2. Sampling

Samples were taken at the inlet and outlet of the station. Water samples were collected using a pole and placed in sterile 500 ml borosilicate glass bottles that had been sterilized beforehand for bacteriological testing. At the same time, 1-liter plastic bottles, previously rinsed with 12% sulfuric acid, were used to collect samples for physical and chemical analysis. A total of 10 samples were taken at the inlet and 10 at the outlet. Samples were taken twice a week. Each sample was stored in a cooler until it was returned to the laboratory.

### 2.3. Determination of physical and chemical parameters

Physicochemical analyses were conducted to measure pH, suspended solids (SS), chemical oxygen demand (COD), and biological oxygen demand (BOD). Several ions were tested for, including nitrate ions, nitrite ions, and phosphate ions.

#### 2.3.1. Physical parameters

The physical parameters studied are pH, temperature, and suspended solids. The pH was measured using the AOAC [10] method with a HANNA pH meter. For TSS, the principle is to measure the amount of solid matter in the solution after filtration through a membrane of known initial mass. After filtration, the membrane is dried in an oven for two hours at 100-105°C and then weighed again. The difference in mass gives the TSS level expressed in mg/L.

#### 2.3.2. Chemical parameters

##### 2.3.2.1. Biological oxygen demand

Biological oxygen demand (BOD) is a commonly used parameter for characterizing water, particularly wastewater from sewage treatment plants or industrial lagoons. It is used to evaluate the biodegradable fraction of carbonaceous pollutant load in wastewater. It corresponds to the amount of oxygen required by microorganisms to partially decompose or completely oxidize 1g of organic substances present in the water into CO<sub>2</sub> within a given time.

The principle is to use an Oxitop manometer to measure the initial concentration of dissolved oxygen in the sample at the time of sampling and the final concentration of dissolved oxygen after five days of incubation in the dark at 20°C [11-12].

##### 2.3.2.2. Chemical oxygen demand

Chemical oxygen demand (COD) is the amount of oxygen required to oxidize the organic and inorganic oxidizable matter contained in a sample [13]. This parameter provides an estimate of the amount of pollutants present in industrial effluent or wastewater. The principle is to oxidize the oxidizable material in the sample by reflux heating in a strongly acidic medium with potassium dichromate in a closed test tube. Oxidizable material in the sample that reacts with the potassium dichromate causes a color change whose absorbance is proportional to the amount of reduced potassium dichromate and is measured in oxygen equivalents. A spectrophotometer is a device used for measurements.

##### 2.3.2.3. Ion measurement

Phosphorus is determined in accordance with AFNOR NF T90-023 [14]. It is measured after mineralization of the phosphorus in the water in the presence of potassium persulfate in an acidic environment at 150°C for two hours. Nitrogen is determined in accordance with AFNOR NF T90-110 [15]. It is measured after mineralization of organic nitrogen into ammoniacal nitrogen in an acidic environment and in the presence of a selenium-based catalyst. During the degradation of organic matter, nitrogen is converted into ammonium ion NH<sub>4</sub><sup>+</sup>, which is oxidized into nitrites and then nitrates by bacteria.

### 2.4. Microbiological enumeration

Microbiological analyses focused on counting thermotolerant coliforms (TTC), *E. coli*, fecal streptococci, and *Pseudomonas aeruginosa*. In addition, *Salmonella* and coliphages were also sought and counted to assess the treatment plant's purification performance.

#### 2.4.1. Counting of thermotolerant coliforms, *E. coli*, and fecal streptococci

The method used is deep plating on a solid medium. The principle consists of taking a 10 ml sample, mixing it with physiological saline, and then performing serial dilutions. The mixture is plated in a Petri dish containing the specific medium. Thermotolerant coliforms and *Escherichia coli* are seeded in Chromocult Coliform Agar medium. Fecal streptococci are seeded in Stanley and Barkley medium. Incubation temperatures are 37°C for *E. coli* and SF, while TTCs are incubated at 44°C. Blue and purple colonies representing *E. coli* are then counted. TTIs produce pink colonies. Streptococci also produce pink colonies.

#### 2.4.2. Counting of *Pseudomonas aeruginosa*

*P. aeruginosa* was identified by surface plating on *Pseudomonas* agar. *Pseudomonas* agar is a selective medium for the isolation and differentiation of *Pseudomonas aeruginosa*. The selectivity of this medium is based on the presence of a quaternary ammonium compound (cetrimide), which inhibits bacteria other than *Pseudomonas aeruginosa*. Once the medium has been prepared, it is sterilized in an autoclave at 121°C for 15 minutes and then distributed into Petri dishes. Dishes seeded with sample and/or diluted sample are then incubated at 42°C for 48 hours. *P. aeruginosa* colonies that develop on agar are yellow-green.

### 2.4.3. Search for *Salmonella*

*Salmonella* identification is carried out in several successive stages. This generally involves enriching the sample, followed by isolation on a specific agar medium. Before enrichment, a pre-enrichment step was carried out by taking 25 mL of wastewater or treated water, adding it to 225 mL of buffered peptone water, and incubating it at 37°C for 24 hours. For enrichment, a volume of 1 mL of the pre-enriched broth was taken and added to 10 mL of enrichment broth (Rappaport), then incubated at 37°C for 24 hours. The positive tubes (those that had changed from dark blue to yellow) were used for the next step. The XLD medium suspension was distributed into Petri dishes, then using a Pasteur pipette, streaks were made on the surface of the solidified media with the solutions from the positive tubes. The dishes were incubated at 37°C for 48 hours. Counting consisted of noting the presence or absence of black colonies.

### 2.4.4. Search for coliphages

The search for coliphages consisted of culturing the strain on Tryptic Soy Agar (TSA) medium that had been prepared in advance, cooled, and poured into Petri dishes. Streaks (close together and wide) were made on the surface of the solidified medium using dilutions containing swabs containing the strain. The dishes were then incubated at 37°C for 24 hours.

### 2.4.5. Reduction calculations

The reductions in the various parameters were determined using the following formula :

$$A = -\log_{10} \left[ 1 - \frac{R}{100} \right]$$

Legend: A= Germs killed (Ulog), R= Purification efficiency (%)

## 2.5. Data processing

The data was entered into Excel and Word version 2016. The average values for the physical and chemical parameters were calculated using Excel 2016 software.

## 3. Results and discussion

### 3.1. Physicochemical parameters

Table 1 shows the average values of physicochemical parameters of samples analyzed.

**Table 1: Average values of physicochemical parameters of samples analyzed**

Parameters	Enter	Outing	Appreciation	Burkina Faso Standard values
pH	9.3	7.6	Conforms	6.5-10.5
COD (mL)	367	198	Conforms	<2000
BOD5 (mL)	50	43	Conforms	<800
PO43- (mL)	52	53	Not conforms	<50
NO3- (mL)	47	26	Not conforms	<90
NO2- (mL)	0.09	0.15	Not conforms	<10
NH4+ (mL)	20,8	21	Not conforms	<150
TSS (mL)	174	166	Conforms	<1000

**Legend :** COD: Chemical oxygen demand ; BOD5 : Biological oxygen demand in 5 days ; Total Suspended Solids: TSS

### 3.1.1. Physical parameters

The pH reported in this study complies with the Burkinabe environmental standard for wastewater discharged into the environment (Table 1). Basic pH values were also reported at the same site by Ouédraogo *et al.* [7] and Kakou [16]. All things considered, the sun's rays shining directly through the water at the site could have an impact on biodiversity. For example, UV rays have a destructive effect on genetic material. These rays are sometimes used to reduce the bacterial load in water treatment plants. Furthermore, the basic water potential of the effluents is thought to be due to chlorinated derivatives [7]. Several studies have reported that chlorinated derivatives in wastewater treatment plants could come from detergents, disinfectants, and pharmaceutical products used in healthcare facilities, households, and cold storage slaughterhouses [7-17]. The TSS loads of different samples comply with the standard value set by the environmental code of Burkina Faso. The average load was 174 mg/l and 166 mg/l at the inlet and outlet, respectively. Armelle and Ajeegah [18] reported averages of 151.67 mg/l and 150 mg/l at the inlet and outlet, respectively, at the same site. These reported values comply with all values set by the Burkinabe environmental standard. The low purification rate of a plant can generally be explained by the colma.

### 3.1.2. Chemical parameters

The assessment of oxygen requirements for chemical degradation of particles (COD) and biological degradation over five days (BOD5) yielded inlet and outlet values that comply with the regulatory standards for wastewater discharge into the environment. A reduction of more than 50% was observed for COD, with a slight reduction for BOD5. These results show that the majority of residual contaminants from the Kossodo WWTP are chemically degradable. COD provides an estimate of the amount of pollutants in wastewater. BOD and COD are parameters used to assess water quality. Kakou *et al.* [16] reported 503.33 mg/l for BOD5 and 744.83 mg/l for COD at the outlet, values that comply with Burkinabe standards for wastewater discharge. Factors such as clogging and rain could reduce the performance of the WWTP. These factors may explain the different values found in these two investigations. Concentrations of phosphate ions, ammonium ions, nitrate ions, and nitrite ions increase after treatment. This increase in values may be due to the degradation of organic matter. Organic nitrogen is converted into ammonium ions, which are then oxidized into nitrite ions and then nitrate ions by bacteria. These ion values comply with discharge standards.

### 3.2. Microbiological parameters

The loads of microorganisms are presented in Table 2 for the inlet and outlet of the WWTP. These results, obtained at the inlet and outlet of the plant, enable us to calculate the average loads of the various pollutants in ten samples analyzed during the study. The first sample will be considered a test sample. These average loads were used to determine the plant's purification efficiency as a percentage and its reduction in Ulog. The results are presented in Table 3 below.

Table 2: Microbial load at the inlet and outlet of the WWTP

Samples	TTC		<i>E. coli</i>		FS		Coliphages		<i>Pseudomonas</i>		<i>Salmonella</i>	
	Enter	Outing	Enter	Outing	Enter	Outing	Enter	Outing	Enter	Outing	Enter	Outing
E0	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
E1	1.48x10 <sup>3</sup>	2.1x10 <sup>3</sup>	3.2x10 <sup>4</sup>	3x10 <sup>2</sup>	3.9x10 <sup>4</sup>	8x10 <sup>3</sup>	NC	NC	NC	NC	NC	NC
E2	6.8x10 <sup>5</sup>	1.1x10 <sup>4</sup>	1.3x10 <sup>5</sup>	2x10 <sup>3</sup>	7.2x10 <sup>5</sup>	10 <sup>5</sup>	2.02x10 <sup>6</sup>	5.6x10 <sup>5</sup>	3.3x10 <sup>6</sup>	9.2x10 <sup>5</sup>	5.2x10 <sup>4</sup>	4.2x10 <sup>2</sup>
E3	2.7x10 <sup>6</sup>	9x10 <sup>4</sup>	8x10 <sup>8</sup>	4x10 <sup>3</sup>	3x10 <sup>5</sup>	0	1.04x10 <sup>7</sup>	10 <sup>6</sup>	1.08x10 <sup>7</sup>	3.2x10 <sup>6</sup>	6.3x10 <sup>4</sup>	5.1x10 <sup>3</sup>
E4	7.9x10 <sup>6</sup>	1.9x10 <sup>5</sup>	9x10 <sup>5</sup>	4x10 <sup>4</sup>	7x10 <sup>5</sup>	2x10 <sup>5</sup>	1.03x10 <sup>7</sup>	10 <sup>6</sup>	6.7x10 <sup>6</sup>	1.6x10 <sup>6</sup>	1.1x10 <sup>5</sup>	6.7x10 <sup>3</sup>
E5	8x10 <sup>6</sup>	5x10 <sup>4</sup>	1.1x10 <sup>6</sup>	10 <sup>5</sup>	2.8x10 <sup>4</sup>	10 <sup>4</sup>	7.6x10 <sup>6</sup>	9x10 <sup>5</sup>	6.2x10 <sup>6</sup>	1.3x10 <sup>6</sup>	3.9x10 <sup>4</sup>	4.3x10 <sup>2</sup>
E6	2.6x10 <sup>7</sup>	7x10 <sup>5</sup>	1.1x10 <sup>7</sup>	0	1.7x10 <sup>4</sup>	6x10 <sup>3</sup>	3.4x10 <sup>7</sup>	1.5x10 <sup>6</sup>	4.1x10 <sup>7</sup>	7x10 <sup>5</sup>	7.9x10 <sup>3</sup>	0.86x10 <sup>2</sup>
E7	8x10 <sup>6</sup>	0	0	5x10 <sup>6</sup>	1.1x10 <sup>4</sup>	4x10 <sup>3</sup>	2.3x10 <sup>7</sup>	1.2x10 <sup>6</sup>	2.7x10 <sup>7</sup>	9x10 <sup>5</sup>	8.3x10 <sup>3</sup>	0.59x10 <sup>2</sup>
E8	1.5x10 <sup>6</sup>	3x10 <sup>4</sup>	3x10 <sup>5</sup>	10 <sup>7</sup>	1.7x10 <sup>4</sup>	9x10 <sup>3</sup>	3.1x10 <sup>6</sup>	1.5x10 <sup>2</sup>	6x10 <sup>6</sup>	1.3x10 <sup>6</sup>	9x10 <sup>3</sup>	0.75x10 <sup>2</sup>
E9	1.3x10 <sup>7</sup>	8x10 <sup>5</sup>	6x10 <sup>4</sup>	3x10 <sup>3</sup>	1.3x10 <sup>4</sup>	6x10 <sup>3</sup>	2.9x10 <sup>7</sup>	2x10 <sup>5</sup>	5.7x10 <sup>6</sup>	3.1x10 <sup>5</sup>	4.7x10 <sup>3</sup>	0.96x10 <sup>2</sup>

Legend: NC = Not Countable; TTC: Thermotolerant Coliforms; FS: Fecal Streptococci

Table 3: Treatment efficiency and reduction in treated water purification

Microorganismes	TTC	<i>E. coli</i>	FS	Coliphages	<i>Pseudomonas</i>	<i>Salmonella</i>
Input load	7.53x10 <sup>6</sup>	1.59x10 <sup>6</sup>	2.03x10 <sup>5</sup>	1.33x10 <sup>7</sup>	1.19x10 <sup>7</sup>	3.27x10 <sup>4</sup>
Output load	4.23x10 <sup>5</sup>	6.7x10 <sup>5</sup>	2.71x10 <sup>4</sup>	5.23x10 <sup>5</sup>	1.14x10 <sup>6</sup>	1.14x10 <sup>2</sup>
Yield (%)	99.43	57.86	86.65	96.06	90.42	99.65
Reduction (Ulog)	2.24	0.37	0.87	1.40	1.01	2.45
Burkina Faso standards (CFU/100mL)	2000	1000	2000			Absence

Legend: TTC: Thermotolerant Coliforms; FS: Fecal Streptococci; CFU: Colony Forming Unit

### 3.2.1. Fecal contamination indicator

Of the ten samples taken, the average microbial loads were  $7.53 \times 10^6$ ;  $1.56 \times 10^6$  and  $2.03 \times 10^5$  CFU/100ml for TTC, *E. coli* and FS respectively at WWTP inlet. Karen et al. [19] found values of  $3.97 \times 10^6$  for *E. coli*,  $9.44 \times 10^6$  for TTC, and  $2.46 \times 10^7$  for SF. At the outlet, we counted loads of  $4.23 \times 10^5$ ;  $6.7 \times 10^5$  and  $2.71 \times 10^4$  CFU/100mL for TTC, *E. coli* and SF, respectively. Karen et al. [19] found similar results with values of  $1.02 \times 10^5$  for TTC,  $7.01 \times 10^5$  for *E. coli*, and  $5.44 \times 10^4$  for FS. These different results do not comply with Burkinabe wastewater discharge standards. The water treatment efficiency of Kossodo WWTP is very low for *E. coli*, which has a value of 57.86% and a reduction of 0.37 Ulog, as well as for SF, which has a reduction of 0.87 Ulog. Clogging of the plant could be the cause of these low reductions. In addition, the failure of industries and slaughterhouses to treat wastewater before discharging it into the sewer system may be a cause of the very high microbial load at the plant's inlet. The treated wastewater is not suitable for discharge into the natural environment in Burkina Faso, as its microbial load exceeds the 2000 CFU/100mL required by standards.

### 3.2.2. Pathogens

At the inlet to the station, loads of  $1.19 \times 10^7$  and  $3.27 \times 10^4$  CFU/100mL of *Pseudomonas* and *Salmonella*, respectively, were counted. Karen et al. [19] found values of  $2.58 \times 10^7$  for *Pseudomonas*, which are proportional to our result, and  $1.89 \times 10^3$  for *Salmonella*. *Pseudomonas* is a hospital pathogen present in all hospital departments, particularly in intensive care units treating infections related to this pathogen, according to Slekovec et al. [20]. According to the same author [20], wastewater from sewer systems containing hospital wastewater is likely to carry a certain amount of this germ. At the outlet of the plant, we counted loads of  $1.14 \times 10^6$  CFU/100mL for *Pseudomonas*. Karen et al. [19] found a value of  $8.70 \times 10^6$  CFU/100mL. These results are broadly similar but do not comply with environmental discharge standards. We note a purification efficiency of around 90.42%. In addition, we note an efficiency of around 99.65% and a reduction of 2.45 Ulog for *Salmonella*. This shows that the plant provides good purification of *Salmonella*. However, given the *Salmonella* load despite good purification, we can conclude that wastewater entering the plant is heavily contaminated with *Salmonella*.

Industries, and especially slaughterhouses, must pre-treat their wastewater before sending it to the plant.

### 3.2.3. Coliphages

The search for coliphages in wastewater stems from their ability to serve as an indicator of fecal viral contamination, and their elimination reflects the effectiveness of virus removal in wastewater treatment plants. Wastewater is loaded with coliphages, with  $1.33 \times 10^7$  CFU/100mL at the inlet and  $5.23 \times 10^5$  CFU/100mL at the outlet of the WWTP. A 96.06% efficiency and a 1.40 Ulog reduction were observed. The plant provides good coliphage purification. However, the wastewater is heavily loaded with microorganisms at the initial stage [21].

## 4. Conclusion

In light of this study, the Kossodo plant treats effluent from breweries, the Ouagadougou refrigerated slaughterhouse, health centers, and households. Most of this wastewater arrives at the WWTP without pre-treatment, with microbial loads and physical-chemical characteristics that do not comply with national standards. This effluent undergoes natural treatment in the plant's various basins. This treatment reduces the microbial load and purifies the physical and chemical parameters of the water leaving the WWTP. The plant shows good purification efficiency for the parameters studied, and the values of the physical and chemical parameters comply with Burkinabe standards for wastewater discharge into the environment. However, the microbial quality of the water at the outlet did not meet Burkinabe standards. The wastewater at the outlet contains pathogens such as *Salmonella* and *Pseudomonas*. These pathogens pose a risk of infection for the users of this water and a risk of toxicity for aquatic flora.

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### Author Contributions

CH, ZO, TP, and OAM: Visualization, Investigation, Formal analysis, Data curation, Writing-original draft, Methodology, and Conceptualization. DAO: Review and editing. AAD, SA, AT, SA: Writing-original draft, Visualization, Supervision, Data curation, and Conceptualization.

**Conflicts of interest:**

All authors declare no conflict of interest.

**Data Availability**

Data presented in this study will be available at the corresponding author's fair request.

**Ethics Approval**

Not applicable to this work.

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