



Physico-chemical and Bacteriological Characterization of Hospital Effluents from Biamba Marie Mutombo Hospital Treated in the UASB Pilot Reactor

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this study was to characterize the wastewater from the BIAMBA Marie MUTOMBO hospital in terms of physico-chemical and bacteriological parameters, and to set up a pilot UASB reactor to treat this water. Two methods were used to conduct the investigations: observation and

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experimentation. Observations focused on wastewater management at the hospital and its surroundings, up to the point of discharge into the receiving environment. The analysis revealed that some parameters, such as COD, BOD₅, turbidity, phosphorus, coliforms and fecal streptococci, exceeded discharge standards. A pilot UASB reactor was therefore proposed to treat the wastewater from the hospital (HBMM). The results were satisfactory, with values in compliance with standards for hospital effluent discharges. At the outlet of the pilot reactor, physico-chemical and bacteriological parameters such as COD showed a reduction in pollutant load of 93.7%, BOD₅ of 93.3%, TSS of 75%, turbidity of 98.6% and phosphorus showed a value in compliance with discharge standards, with a reduction of 50%. Fecal coliforms at the outlet showed an efficiency of 100% and fecal streptococci of 99.9%, proving the effectiveness of the UASB pilot system for treating hospital effluents from the hospital (HBMM). This study has therefore shown that the implementation of a UASB pilot reactor can contribute to improving efficiency in the treatment of wastewater from Biamba Marie Mutombo Hospital.

Keywords: Characterization; hospital effluents; physico-chemical; bacteriological; treated; UASB; Biamba Marie Mutombo Hospital.

1. INTRODUCTION

1.1 Problematic

The treatment of wastewater before its discharge into the natural environment is a major challenge for many countries in the world, particularly for developing countries that suffer from a lack of capital and face anarchic urbanization and industrialization. In Africa, the situation of wastewater evacuation and treatment is dramatic. Many studies highlight the harmful consequences of poor hygiene, both in terms of health, environment and economy [1-4] indicates that hundreds of millions of people worldwide suffer from schistosomiasis, cholera, typhoid fever, worms responsible for various health disorders and other infectious diseases. In addition, 3.5 million children die each year from diarrhea caused by poor sanitary conditions [5] reports that 51% of African countries are facing severe environmental pollution that could threaten water resources. In the current global context marked by population explosion and industrial development, effective waste management has become a major concern for the international community. Among all types of waste, biomedical waste (BMW) requires special attention due to the risks it poses to the environment and human health. Thus, it is essential for sustainable development to be concerned with BMW management in developing countries. Hospitals can be a source of pollution that is important to take into account in a general approach to assessing health and environmental risk. Studies conducted so far conclude that hospital effluents are of similar quality to domestic effluents [6]. However, the importance of water volumes consumed leads to pollutant

flows per hospital bed higher than those defined for an equivalent inhabitant [7]. In addition, it seems that discharges from certain services, such as radiotherapy or contagious services, may be considered risky. Hospital waste management has become widespread, and it may be necessary to consider the case of discharges. The treatment of wastewater from hospital centers located in small or medium-sized agglomerations poses a real environmental problem. These waters are indeed loaded with microorganisms, some of which are multi-resistant, as well as chemical and even radioactive products. It is therefore important that technological advances in care, such as hemodialysis, radiology and high-tech laboratories, do not harm the aquatic ecosystem of rivers and seas. However, the city of Kinshasa has about 12 million inhabitants and 2080 medical formations, public and private, are listed, according to a report from the Urban Health Division dating from 2011, among which is the Biamba Marie Mutombo Hospital (HBMM). The majority of wastewater from agglomerations and hospital structures is currently discharged into the natural environment without any prior treatment. While Article 4 of the New Water Law prohibits discharges, flows, releases, infiltrations, burials, spreading, direct or indirect deposits in water of any solid, liquid or gaseous matter and in particular industrial, agricultural and atomic waste likely to alter the quality of surface or groundwater, or sea water within territorial limits; to harm public health as well as aquatic or submarine fauna and flora; to call into question the economic and tourist development of regions [8]. Thus, the implementation of a hospital effluent treatment system, in this case the UASB reactor, is an adequate alternative for treating

effluents before discharging them into the natural environment. The Upflow Anaerobic Sludge Blanket (UASB) reactor was developed by Professor Lettinga and his colleagues in the late 1970 [9]. The system is capable of handling high volumetric loading rates of 10-15 kg in chemical oxygen demand. This reactor is a reliable system and can treat up to 15% of total suspended matter [10,11]. Wastewater enters the reactor from the bottom of the reactor through a special distribution system. No agitation device is installed. The necessary mixing between wastewater and biomass is achieved through biogas production and turbulence due to the upflow entering the reactor.

1.2 Objectives of the Study

The aim of this work was to carry out a characterization of the hospital wastewater generated by the Biamba Marie Mutombo Hospital, with a view to treating it through a pilot UASB reactor. The specific objectives are:

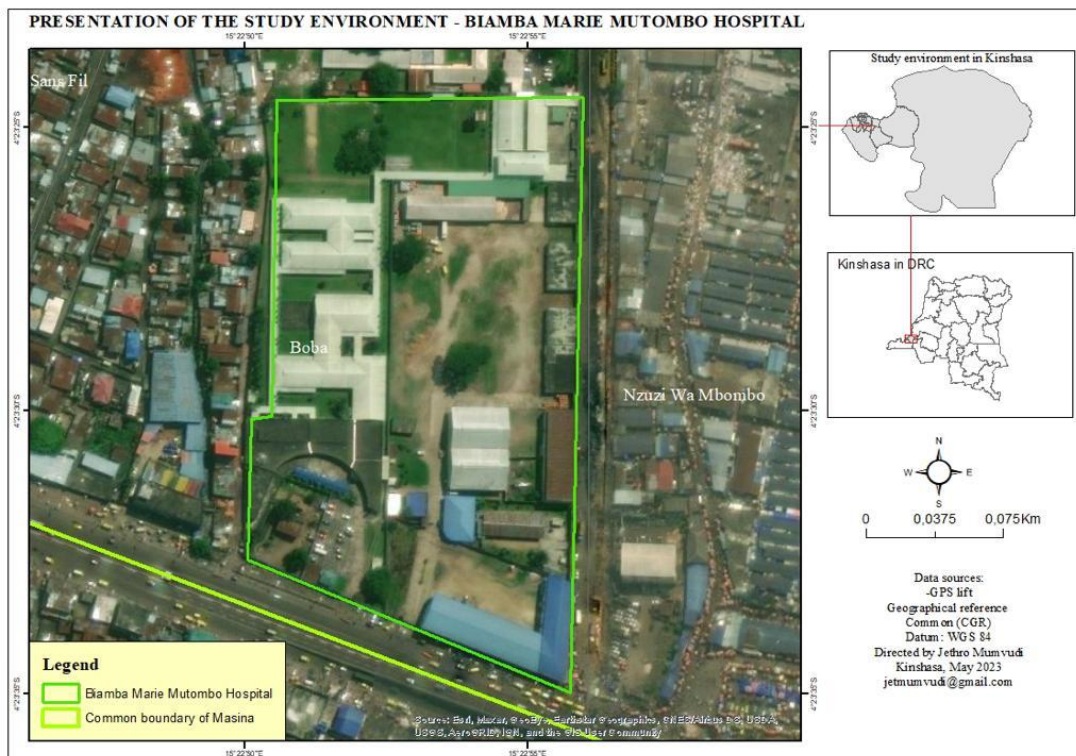
- to determine the physico-chemical and bacteriological characteristics of the hospital wastewater from the Biamba Marie Mutombo Hospital;
- to install a pilot UASB reactor in the laboratory to monitor the treatment of

hospital wastewater over a specific period and to treat wastewater in the pilot UASB reactor in order to compare UASB outputs with hospital wastewater discharge standards.

2. STUDY SITE, MATERIAL AND METHODS

This work was carried out in the city Province of Kinshasa, more specifically at the Biamba Marie Mutombo Hospital in the MASINA commune (see map 1).

The Biamba Marie Mutombo Hospital (HBMM) is a healthcare facility in Kinshasa, Democratic Republic of Congo, that was inaugurated in 2007. It is part of the Dikembe Mutombo Foundation, a Congolese non-governmental organization. The hospital has about ten medical services, such as Pediatrics, Internal Medicine, Surgery, Obstetrics and Gynecology, Laboratory, Intensive Care, Medical Imaging, Emergency, ENT, Physiotherapy, outpatient consultations and a reception structure. It has a capacity of about 300 beds and a staff of 186 members. The hospital receives an average of 120 to 150 patients per day or 3600 to 4500 patients per month.



Map 1. Geographical location of the Biamba Marie Mutombo Hospital

2.1 Materials and Methods

This work consisted of characterizing the hospital wastewater of HBMM for treatment by the UASB pilot reactor. Initially, it is important to identify hospital services that are closer to an industrial or domestic activity in order to define the establishment's status in terms of environmental protection, particularly whether it should be considered as a classified installation. This study will also determine the urgency and interest of appropriate management of hospital effluents, depending on the degree of risk they present and the stakes for the various stakeholders (quality assurance for hospitals, protection of the population and environment for health and environmental institutions). To carry out this field study, hospital wastewater was used as material. The other materials used included:

- Plastic bottles for sampling hospital wastewater.
- A cooler to keep effluents in similar isothermal conditions.
- A multi-probe for in situ analysis.
- A UASB pilot reactor mounted in the laboratory.

Two methods were used to conduct investigations: the observation method and the experimentation method. Observations focused on the state of management of hospital wastewater. Observation was also extended to the surroundings of the hospital, up to the point of discharge of wastewater into the receiving

environment. This data is essential for assessing the environmental impact of hospital wastewater and identifying potential health risks. Experimentation was carried out to characterize the hospital's wastewater, in order to treat it in the laboratory UASB pilot reactor. We proceeded as follows:

2.1.1 Installation of the UASB pilot system for treating effluent from HBMM hospital

A 500 ml glass UASB pilot device was set up in the Ecotoxicology, Chemical Safety and Environmental Biotechnology laboratory of the Environmental Science and Management program at the Faculty of Sciences of the University of Kinshasa. This reactor consists of a cylinder with two tapered ends and two parallel outlets on the upper part. At the bottom of the reactor is the inlet for effluent and towards the top is the outlet for biogas collected using a 100 ml glass bottle. The purified water and recirculation of water to reactivate effluent through the bacterial inoculum process that has already circulated in the device are done through the parallel outlets.

The UASB reactor was connected upstream by a sealed reservoir with a tap (15L) to store wastewater and downstream by a recovery basin (20L) to collect purified water. The water flow is done by drops through piping with a known flow rate of 0.869 ml per minute or $0.014483 \cdot 10^{-6} \text{ m}^3/\text{s}$, thus allowing for a well-determined hydraulic residence time of about 10 hours.

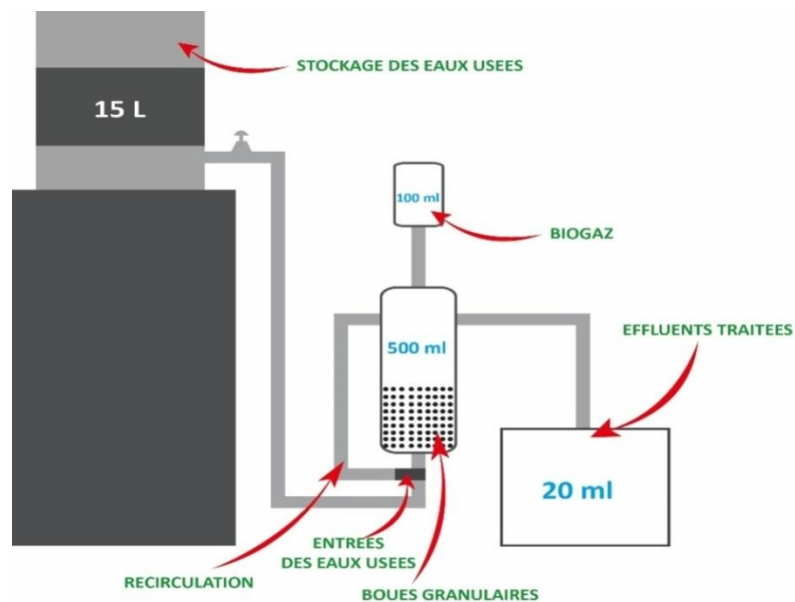


Fig. 1. UASB pilot reactor

➤ Hydraulic residence time

The hydraulic residence time (HRT) corresponds to the total time required for wastewater to flow through the entire system. It is calculated by dividing the total volume of the reactor by the incoming water flow rate. The conditions of the environment in our treatment system favor the growth and activity of methanogenic microorganisms, which use suspended organic matter in water for their organic carbon and energy necessary for their survival. This microbial activity is favorable for the degradation of organic matter, thus leading to the production of biogas.

The UASB pilot reactor is designed to have a well-determined hydraulic residence time and favorable conditions for methanogenic microorganisms, thus allowing for efficient degradation of organic matter and biogas production.

2.1.2 Sampling, collection and laboratory analysis

Samples were collected in plastic bottles with a capacity of one liter (1L) to collect hospital wastewater (HBMM), as well as at the inlet and outlet of the UASB pilot system. The following parameters were chosen based on the objectives of the study: temperature, pH, conductivity, dissolved oxygen and turbidity were measured in situ. In the laboratory, the following parameters were analyzed: suspended solids (SS), phosphorus, ammonium, nitrates, TKN, chemical oxygen demand (COD), biological oxygen demand (BOD₅), coliforms and fecal streptococci.

2.1.3 Physicochemical analyses

The pH measurement was carried out using a SELECTA brand digital pH meter pH-2005, the electrical conductivity was measured using a SELECTA brand digital conductivity meter CD-2005, the turbidity was determined using a TurbiDirect/Lovibond brand turbidimeter based on the nephelometric method, The determination of suspended solids was determined by the filtration and weighing method, the measurement of Chemical Oxygen Demand (COD) was done by the so-called closed reflux "reactor digestion" method. The manometric method was used to measure the 5-day biochemical oxygen demand (BOD₅) using an OxiDirect/Lovibond brand oximeter. The persulfate mineralization method was used to measure total nitrogen. Nitrate ions

were quantified by the chromotropic acid method using an MD/600 brand photometer. The indophenol method was used to determine ammoniacal nitrogen. The Ammonium-molybdate method was used to determine ortho phosphates.

2.1.4 Bacteriological analyses

Bacteriological analyses aim to evaluate the purification performance of the treatment plant in sanitary terms, i.e., its ability to eliminate pathogenic germs. The microorganisms used as bio-indicators of fecal pollution are fecal coliforms (FC) and fecal streptococci (FS), including *Escherichia coli* (*E. coli*) and *Enterococcus* sp., respectively [7,12]. Fecal Streptococci (FS) and fecal coliforms were evaluated using the decimal dilution method.

2.1.5 Data analysis

The data obtained were divided into physicochemical and bacteriological parameters and were entered using Excel 2016 and Matlab/Simulink 2013 software.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Physico-chemical parameters and bacteriological

The results of the physico-chemical and bacteriological parameters before and after treatment in the UASB pilot reactor are detailed in Table 1. In effect, the UASB pilot reactor showed effective removal of the pollutant load from the hospital effluents of Biamba Marie Mutombo Hospital (HBMM) by physicochemical treatment. The physicochemical parameters measured at the outlet of the system were significantly lower than those at the inlet. COD decreased from 449±1.2 mg/l to 28±1.2 mg/l, with an efficiency of 93.7%. BOD₅ decreased from 135±1.9 mg/l to 9±1.3 mg/l, with an efficiency of 93.3%. The suspended solids load decreased from 100±0.9 mg/l to 25±1.9 mg/l, with an efficiency of 75%.

Turbidity decreased from 179±1.3 mg/l to 2.5±1.9 mg/l, with an efficiency of 98.6%. Dissolved oxygen increased from 1±0.1 mg O₂/l to 5.4±1.2 mg O₂/l, a value that meets the standard. Total nitrogen decreased from 41±1.8 mg N/l to 24.2±1.1 mg N/l at the outlet, while ammonium decreased from 2.4±1.8 mg/l to 1.75±1.7 mg/l.

Nitrate decreased from 30±0.8 mg/l to 9±1.3 mg/l at the outlet, with an efficiency of 70%. Phosphorus decreased from 2.2±1.8 mg/l to 1.1±0.3 mg/l at the outlet. Conductivity slightly changed from 480±1.8 µS/cm to 420±1.2 µS/cm at the outlet, pH changed from 7.3±0.3 to 6.9±0.1 and temperature increased from 28±0.21°C to 29±1.9°C.

3.1.2 Physicochemical purification performance of the UASB pilot reactor for hospital wastewater from the hospital (HBMM)

The reductions for each parameter were calculated using the following formula [13]. The physicochemical reduction percentage of the hospital effluents from Biamba Marie Mutombo hospital by the UASB pilot reactor ranged from 70% to 100%, depending on the parameter measured. The respective values were 75% for TSS, 98.6% for turbidity, 93.7% for COD, 93.3% for BOD₅, 85.7% for dissolved oxygen, and 70% for nitrates.

The UASB pilot reactor performance was satisfactory, and according to [14], physicochemical reductions above 60% are acceptable for wastewater treatment in warm climates. The UASB pilot system also showed high purification performance for the hospital effluents from Biamba Marie Mutombo hospital, with values of 100% for fecal coliforms and

99.9% for streptococci. These results met the standard limit values. Fecal coliforms decreased from 44000 CFU/100ml to 0 CFU/100ml, with an efficiency of 100%, while fecal streptococci decreased significantly from 70000 CFU/100ml to 5 CFU/100ml, with an efficiency of 99.9%.

3.1.3 Bacteriological parameters at the inlet and outlet of the UASB pilot system treating hospital wastewater from the hospital (HBMM)

The bacteriological parameters, namely fecal coliforms and fecal streptococci, in the hospital wastewater from Biamba Marie Mutombo hospital (HBMM) showed significant reductions at the outlet of the pilot treatment system, with values well below the standard and efficiencies of 100% for fecal coliforms and 99.9% for fecal streptococci. This demonstrates the effectiveness of the UASB pilot system in removing the bacteriological pollutant load. Here is a possible rewrite of the scientific text: The bacteriological parameters, namely fecal coliforms and fecal streptococci, in the hospital wastewater from Biamba Marie Mutombo hospital (HBMM) showed significant reductions at the outlet of the pilot treatment system, with values well below the standard and efficiencies of 100% for fecal coliforms and 99.9% for fecal streptococci. This demonstrates the effectiveness of the UASB pilot system in removing the bacteriological pollutant load.

Table 1. Physico-chemical and bacteriological characteristics of hospital effluents from the hospital at the entrance and exit of the UASB pilot system compared to discharge standards

N°	Physico-chemical parameters	Limit value (EU, 2011 and WHO, 2006)	Results obtained		
			E ₁	E ₂	Efficiency (%)
1	Temperature	≤ 30	28±2	29±1.9	-
2	pH	5.5 – 8.5	7.3±0.3	6.8±0.1	-
3	Turbidity NTU	≤ 10 NTU	179±1.3	2.5±1.9	98.6
4	Dissolved oxygen O ₂ (mg/l)	> 5 mg/l	1±0.1	5.4±1.2	-
5	Conductivity	≤ 1500 µS/cm	480±1.8	420±1.2	-
6	Suspended matter	≤ 35 mg/l	100±0.9	25±1.9	75
7	Chemical Oxygen Demand	≤ 90 mg O ₂ /l	449±1.2	28±1.2	93.7
8	biochemical oxygen demand the 5-day	≤ 30 mg O ₂ /l	135±1.9	9±1.3	93.3
9	Phosphorus	≤ 2 mg to P/l	2.2±1.8	1.1±0.3	50
10	Ammonium	≤ 2 mg N/l	2.4±1.8	1.75±1.7	27
11	Total nitrogen	≤ 50 mg N/l	41±1.8	24.2±1.1	41
12	Nitrate	≤ 50 mg N/l	30±0.8	9±1.3	70

Where:

- E₁: Untreated hospital wastewater;
- E₂: Effluent treated in the UASB pilot reactor.

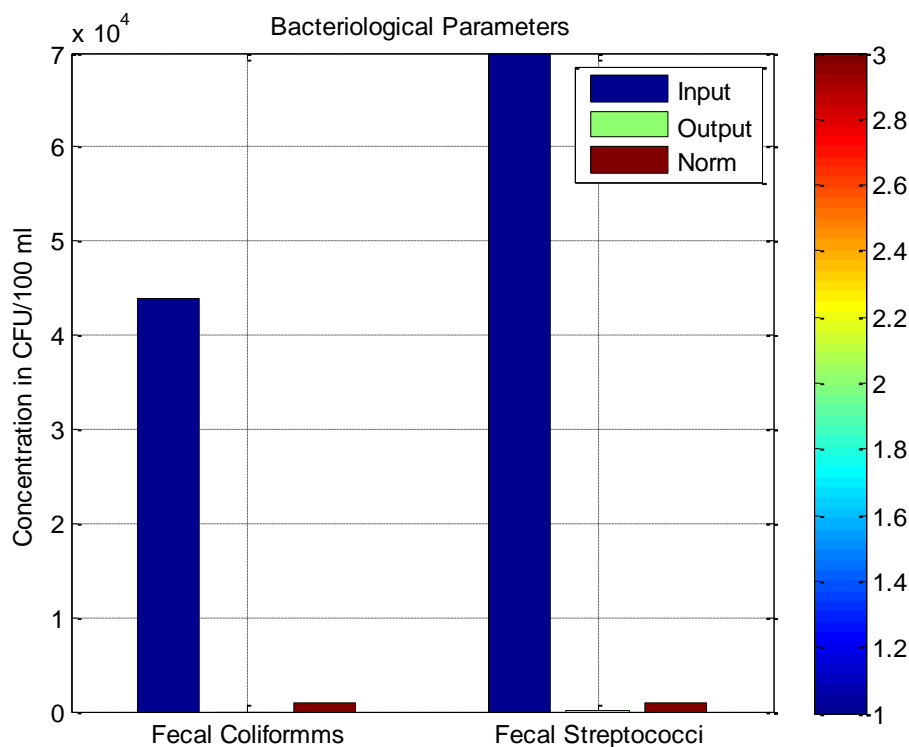


Fig. 2. Bacteriological parameters of hospital effluents before and after treatment in the UASB pilot reactor

3.2 Discussion

The effect of pollutant load on the purification efficiency of the UASB pilot reactor was evaluated by measuring the concentrations of physicochemical and bacteriological parameters in the wastewater from Biamba Marie Mutombo Hospital and the UASB pilot system. The evaluated parameters were pH, temperature, turbidity, dissolved oxygen, conductivity (CND), phosphate ions (PO_4^{3-}), nitrate ions (NO_3^+), chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), fecal coliforms (FC) and fecal streptococci (FS). The system's performance was calculated based on the average pollutant load at the inlet and outlet of the UASB pilot reactor. However, a UASB pilot reactor installed in the laboratory of Ecotoxicology, Chemical Safety and Environmental Biotechnology gives results that comply with discharge standards for physicochemical and bacteriological parameters for the treatment of hospital wastewater. The physicochemical and bacteriological parameters underwent a significant reduction in pollutant load at the outlet of the UASB pilot reactor, with values such as: COD dropping from 449 ± 1.2 mg/l at the inlet of the reactor to 28 ± 1.2 mg/l at

the outlet, BOD_5 dropping from 135 ± 1.9 mg/l at the inlet of the reactor to 9 ± 1.3 mg/l at the outlet, total nitrogen dropping from 41 ± 1.8 mg/l at the inlet to 24.2 ± 1.1 mg N/l at the outlet, phosphorus dropping from 2.2 ± 1.8 mg/l at the inlet to 1 ± 0.3 mg P/l at the outlet, nitrate content dropping significantly from 30 ± 0.8 mg/l at the inlet to 9 ± 1.3 mg N/l at the outlet of the pilot system. At the outlet of the system, ammonium content dropped from 2.4 ± 1.8 mg/l at the inlet to 1.75 ± 1.7 mg N/l at the outlet. The suspended solids (SS) content dropped from 100 ± 0.9 mg/L at the inlet of the system to 25 ± 1.9 mg/l at its outlet, and turbidity also dropped from 179 ± 1.3 at inlet to 2.5 ± 1.9 NTU at outlet. Dissolved oxygen is of paramount importance. Indeed, areas deprived of dissolved oxygen by pollution cause death by asphyxiation. Note that this parameter varies considerably. It goes from 1 ± 0.1 mg O_2 /l at the inlet to 5.4 ± 1.2 mg O_2 at the outlet of the pilot reactor. Electrical conductivity (EC) is a numerical expression of a solution's ability to conduct electrical current; it provides information on mineral pollution, which varies from 480 ± 1.8 $\mu\text{S}/\text{cm}$ at the inlet of the system to 420 ± 1.2 $\mu\text{S}/\text{cm}$ at the outlet, with a temperature of $29 \pm 1,9^\circ\text{C}$ at the outlet. The pH measured in the field and that measured in the

laboratory did not show great variations, being 7.3 ± 0.3 in the field and 6.8 ± 0.1 in the laboratory.

According to a study conducted by [15] on the physico-chemical, bacteriological and ecotoxicological characterization of effluents from the University Clinics of Kinshasa and their treatment in a UASB system, the pilot system set up was able to produce satisfactory results, notably the COD which had dropped from 6250 mg/l at the reactor inlet to 20mg/l at the outlet, representing a 99.7% reduction, the BOD₅ which went from 200mg/l at the system inlet to 0 mg/l at the outlet, representing a 100% reduction in pollutant load. Nitrate, on the other hand, had dropped from 240 mg/l to 45mg/l at the reactor outlet, TSS fell from 1169 mg/l to 11 mg/l at the system outlet, fecal coliforms went from 1.5×10^6 CFU/100ml to 0 CFU/100ml at the system outlet. The values found by [16] on hospital wastewater from the University Clinics of Kinshasa are satisfactory with the reduction of all pollutant load and correspond to the results found in our study for the treatment of hospital wastewater from Biamba Marie Mutombo Hospital. This shows sufficiently the effectiveness of the UASB system in treating hospital wastewater. The study conducted by [17] showed that the UASB system of BB Lomé S.A brewery produced satisfactory values, with a reduction of 80% for COD and 99.31% for BOD₅. The results obtained by this study correspond to those obtained by our study, confirming the effectiveness of this industrial wastewater treatment system. Similarly, a study conducted by [17] showed that the UASB process coupled with a slow sand filter used for depollution of leachate from Mpsa technical landfill center in Kinshasa (DRC) also produced satisfactory results. The BOD₅ removal was 92%, COD was significantly reduced with a yield of 98%, and TSS were reduced with a purification yield of 84.3%. These results were similar to those obtained in our study on the effectiveness of hospital wastewater treatment by the UASB pilot reactor. In summary, the results of the studies conducted by [16] and [17] confirm the effectiveness of the UASB reactor in reducing pollutant load and more broadly in treating hospital wastewater. These results can be useful for improving wastewater treatment processes in other similar contexts.

4. CONCLUSION

This study has therefore shown that the implementation of a UASB pilot reactor can contribute to improving efficiency in the treatment

of wastewater from Biamba Marie Mutombo Hospital. The evaluation of the purifying performance of the UASB pilot reactor in the treatment of wastewater from Biamba Marie Mutombo Hospital showed a significant reduction in pollutant load, with a COD yield of 93.7%, a BOD₅ of 93.3%, a 75% reduction in Suspended Solids (TSS), a 98.6% reduction in turbidity, a 100% reduction in fecal coliforms and a 99.9% reduction in fecal streptococci.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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