INFLUENCE OF TREATED EFFLUENT FROM THE QUILOMOSSO WWTP (UÍGE, ANGOLA) ON THE QUALITY OF THE BOLONGONZO RIVER BASED ON COD AND BOD INDICATORS.

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Abstract

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This study examined wastewater management in the city of Uíge, focusing on the Quilomosso area, with the aim of assessing the effectiveness of the existing treatment system and the environmental impacts of effluent discharge into the Bolongonzo River. Analyses of parameters such as Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD) showed that at the inlet, average values were 470 mg/L for BOD_5 and 1558 mg/L for COD, which is expected due to the high pollutant loads in the raw water. After the decantation stage, at the decanter outlet, the parameters dropped to 5 mg/L for BOD_5 and 48 mg/L for COD, indicating significant efficiency in solid separation. Finally, at the point of discharge into the river, the measured values were 3 mg/L for BOD_5 and 41 mg/L for COD, both within the limits set by Angola's Presidential Decree 261/11. It was recognised that the final effluent disposal has a regulated impact but could be optimised to align with environmental sustainability principles. Based on these results, suggestions included improving maintenance of the treatment infrastructure and enhancing effluent quality monitoring.

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Introduction:-

Water is an essential resource that sustains ecosystems, supports human life, and drives sectors such as industry and agriculture. The demand for freshwater has been steadily increasing as the global population grows (Kato &Kansha, 2024). Efficient wastewater management is a critically important challenge in many cities around the world, which mainly deal with wastewater from domestic, medical, and industrial sources (Inarmal& Moodley, 2024); the town of Uíge, in particular, is no exception. The centrality of Quilomosso, located in this region, becomes a relevant case study to understand the specific challenges faced in managing urban wastewater. Aligned with Goal 6.2 of the United Nations Sustainable Development Goals (UN), agreed upon in September 2015, the Ministry of Energy and Water of Angola developed a priority action plan for the country's development, which set the goal of eliminating open defecation by 2030.(Matos et al., 2021). The plan focuses on studies of sustainable wastewater collection and treatment (Matos et al., 2021). This study will address different aspects of wastewater in the Quilomosso Centrality toanalyse the impact of discharging treated effluent into the Bolongonzo River byassessing carbonaceous pollution,COD, and BOD_5. The technologies used in the WWTP will be examined, as will their efficiency in removing organic load from effluents and their compliance with established environmental standards.

Theoretical Framework:

Implementation of wastewater treatment plants (WWTPs)

Implementing wastewater treatment plants is essential but challenging to prevent water pollution and satisfy water demand (Kato &Kansha, 2024). Around 25% of the world's biggest cities are already experiencing severe water stress, and 2.2 billion people still lack access to safe drinking water (Imteaz et al., 2025). The most common type of WWTPs located in urban areas uses the activated sludge treatment method (Inarmal& Moodley, 2024; Matos et al., 2021) for the removal of various compounds. This includes, but is not limited to, nutrients and inorganic compounds. This method is efficient because it ensures high nutrient, organic matter, and suspended solids removal at a relatively low operational cost (Inarmal& Moodley, 2024).

Principle of operation of the Quilomosso WWTP

The wastewater treatment plant implemented at the Quilomosso Centrality (operation scheme shown in Figure 1) uses the anaerobic/anoxic/aerobic (AAA) process(Luo et al., 2025), systematically sequenced through the preliminary, primary, secondary, and tertiary phases (Kato &Kansha, 2024),which allows for the effective reduction of organic matter abundance.

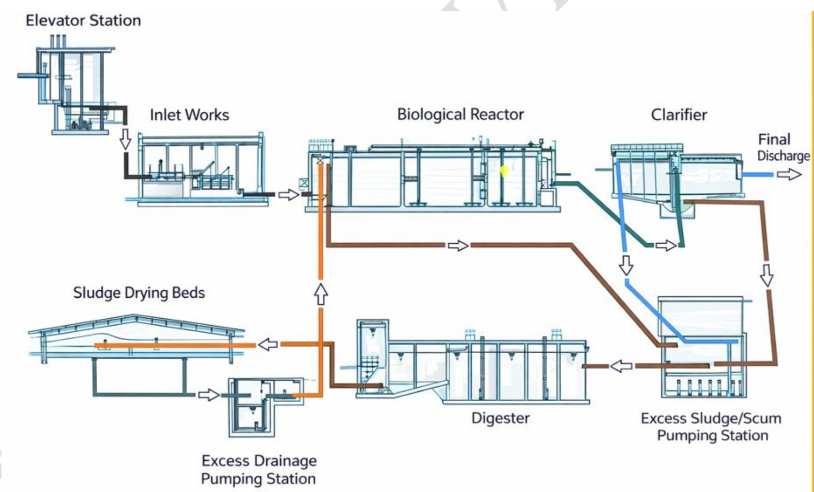

Figure1. Operational scheme of the Quilomosso Centrality WWTP.

Figure 2 shows the typical flowchart of the wastewater treatment process (WWTP) and the corresponding techniques.

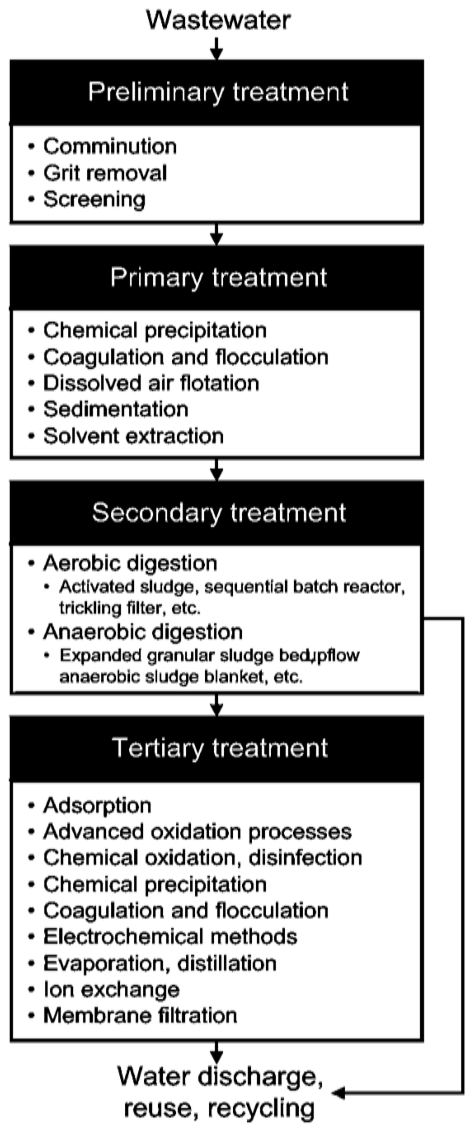

Figure2. The overall flow of a wastewater treatment process and the techniques used (Kato &Kansha, 2024).

Efficiency and sustainability of WWTPs

The efficiency of a wastewater treatment system can be evaluated by the reduction of parameters such as turbidity, hardness, conductivity, total dissolved solids, total suspended solids (TSS), chloride (Cl^-), ammoniacal nitrogen (NH_3–N), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total coliforms (Imteaz et al., 2025). The removal efficiencies in various wastewater treatment plants (WWTPs) vary due to multiple factors, including the physicochemical properties of the compound, climatic conditions (such as temperature, sunlight, and precipitation), and operational conditions of the treatment (related to temperature, redox conditions, and retention times), as well as the time and state of activated sludge(Inarmal&

Moodley, 2024). Determining organic matter is one of the most significant challenges, as it encompasses all compounds that contain carbon and other elements, such as hydrogen, oxygen, and nitrogen(Aguilar-Torrejón et al., 2023).Thus, identifying your presence and concentration requires a different kind of analysis, usually assessed using the chemical oxygen demand (COD)test (Han et al., 2014) and the biochemical oxygen demand (BOD) test (Rudaru et al., 2022). Water monitoring is essential for determining the substances released into the environment and for better understanding WWTP processes, providing valuable information for decision-making(García-Martínez et al., 2025). Wastewater treatment plants (WWTPs) are recognised as a key barrier in preventing pollutants from entering natural ecosystems(Luo et al., 2025; Wu et al., 2023). It is worth noting that wastewater can be treated to meet the quality requirements for irrigation and other agricultural uses. An additional treatment can also expand the supply of drinking water. This approach ensures that no resource is overlooked, maximising a resource that would otherwise be completely discarded (Silva, 2023).

Ratio between BOD_5 and COD: parameters in water for organic matter assessment

Efficient management and control of wastewater pollution are essential for sustainable development, especially as water demand increases at twice the rate of population growth(Diwyanjalee et al., 2024). A primary distinction between BOD and COD lies in the fact that COD evaluates all the organic matter present, including biodegradable and non-biodegradable compounds, while BOD is limited to quantifying the organic matter that is or can be biologically degraded, that is, the biodegradable fraction of wastewater (Diwyanjalee et al., 2024; Rudaru et al., 2022; Wei et al., 2023). In recent studies, the BOD/COD ratio has emerged as a prominent indicator of the biodegradability of total organic carbon. It serves as an indicator of a contaminant's ability to reduce oxygen levels in wastewater(Diwyanjalee et al., 2024). The BOD/COD ratio should be less than or equal to 1.0. However, this ratio is only an indicator of the fraction of biodegradable organic matter present in the wastewater (Aguilar-Torrejón et al., 2023). The values reported in the literature for the BOD/COD ratio, or biodegradability index (BDI), range from 0.4 to 0.8 for wastewater considered readily biodegradable and from 0.1 to 0.2 for wastewater that is difficult to treat biologically or contains substances toxic to activated sludge microorganisms. Among values from 0.2 to 0.5, the microorganisms responsible for biological degradation need to be adapted to the wastewater influent of the wastewater treatment plant(Rudaru et al., 2022).Understanding the microbial population present in activated sludge is essential for wastewater treatment, as it helps assess microbial resistance to pollutant toxicity and the biodegradability of the water. Wastewater with a BOD/COD ratio of around 0.5 provides excellent stability and efficiency to the microbial community(Wei et al., 2023). The biodegradability index (BDI) is also a useful indicator for assessing the organic matter content in river water(Rudaru et al., 2022).

Materials and Methods:-

Location and description of the study area:

The centrality of Quilomosso – Uíge (Figure 3), located 5 km from the city centre of Uíge, was inaugurated on August 10, 2018. It was designed for 4,500 housing units. In this first phase, 1,010 houses were built, including 752 apartments, 82 single-family homes, and 176 duplex houses, as well as social infrastructure such as primary and secondary schools, health clinics, a childcare centre, and a kindergarten, along with a potable water production and supply system and domestic wastewater treatment. The Quilomosso Centrality's wastewater treatment plant has a capacity of 6,600 m³/day.

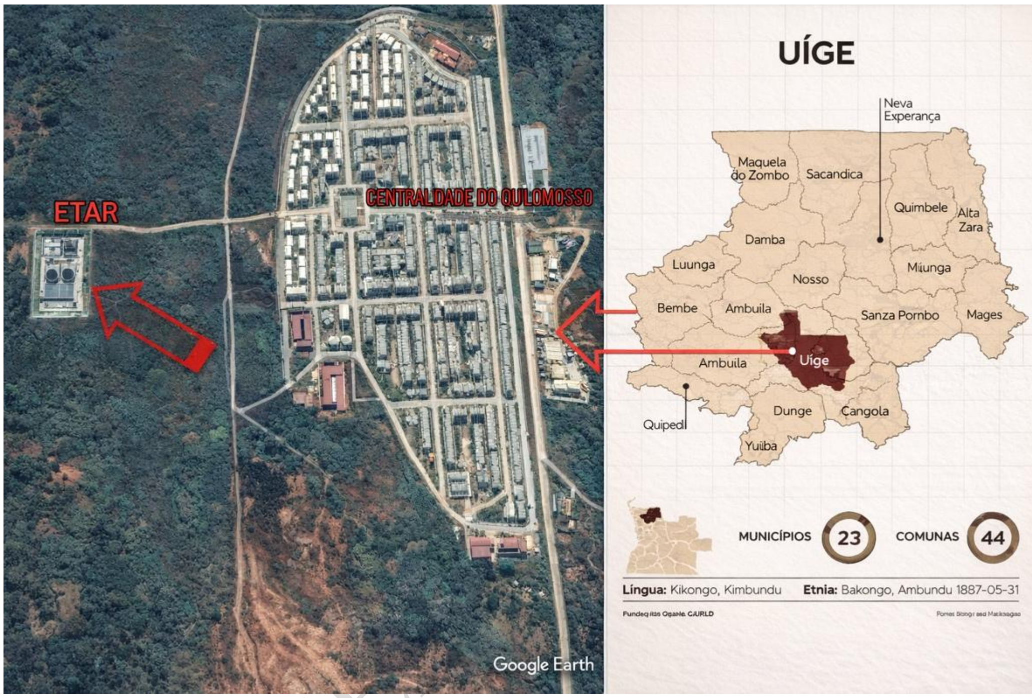

Figure 3. Study Area. Adapted from (Assembleia Nacional, 2024).

Sampling locations

Wastewater samples were collected at different strategic points of the Wastewater Treatment Plant (WWTP): upstream of the plant — the inlet works (P1) — to assess the initial pollutant load before any treatment; in the secondary clarifier (P2) — to verify the efficiency of solids and matter removal after sedimentation; and in the Bolongonzo River (P3) — to evaluate the impact of the discharged treated effluent on the receiving ecosystem. The sample volume (Figure 4) was 1000 mL at all collection points.

Figure 4. Representative samples of wastewater at the Quilomosso WWTP, corresponding to the raw sewage entry points, the treated effluent outlet, and the discharge into the Bolongonzo River, for analysis of COD and BOD_5 parameters.

The samples were collected regularly and rigorously, in accordance with the technical standards for preservation and integrity described by Lipps et al. (2023), ensuring reliable and accurate results. Subsequently, they were transported to the AMBIÁFRICA laboratory, located on Cauaco Road, km 4 Caxito, Panguila, Luanda, where the tests were conducted. This approach enabled a detailed assessment of the wastewater treatment process, allowing the identification of potential failures and the proposal of concrete solutions to improve the wastewater management system at the Quilomosso Centrality.

Determination of the efficiency of the QuilomossoWWTP and the BOD / COD ratio

To calculate pollutant removal efficiency, Equation 1 was used, asdescribed by Pérez et al. (2024). This method is widely accepted in the literature on sanitary engineering studies (Kachienga et al., 2025).

$$\%R_E = \frac{\mathbf{C}_{\text{inlet}} - \mathbf{C}_{\text{outlet}}}{\mathbf{C}_{\text{inlet}}} \times 100\% \qquad (1)$$

where:$\%R_E$= Pollutant Removal Efficiency;$\mathbf{C}_{\text{inlet}}$= Concentration of the analysed parameter at P1;$\mathbf{C}_{\text{outlet}}$= Concentration of the analysed parameter at P2 and P3;

It should be noted that calculating removal efficiency based on simultaneous inlet and outlet measurements has no physical significance; such a procedure,therefore, does not reflect the actual pollutant removal efficiency. The portion of wastewater entering (P1) requires a residence time to be removed under steady flow conditions. This consideration must be considered. Only samples collected at two different times, at the inlet and outlet, can be used to assess the pollutant removal efficiency(Pérez et al., 2024).

The biodegradability index (BDI) of each sample was calculated using the following equation(Diwyanjalee et al., 2024):

$$BDI=\frac{BOD_5}{COD} \qquad (2)$$

Results and Discussions:-

Figure 5 shows the values of BOD_5 (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) collected at the three sampling points, along with the limits established by Angolan Presidential Decree No. 261/11(DecretoPresidencialn.o 261/11 de 06 de outubro, 2011). As expected, the values of both parameters at P1 are well above the established limits, confirming that the wastewater from the Quilomosso central area carries a high organic and chemical load.

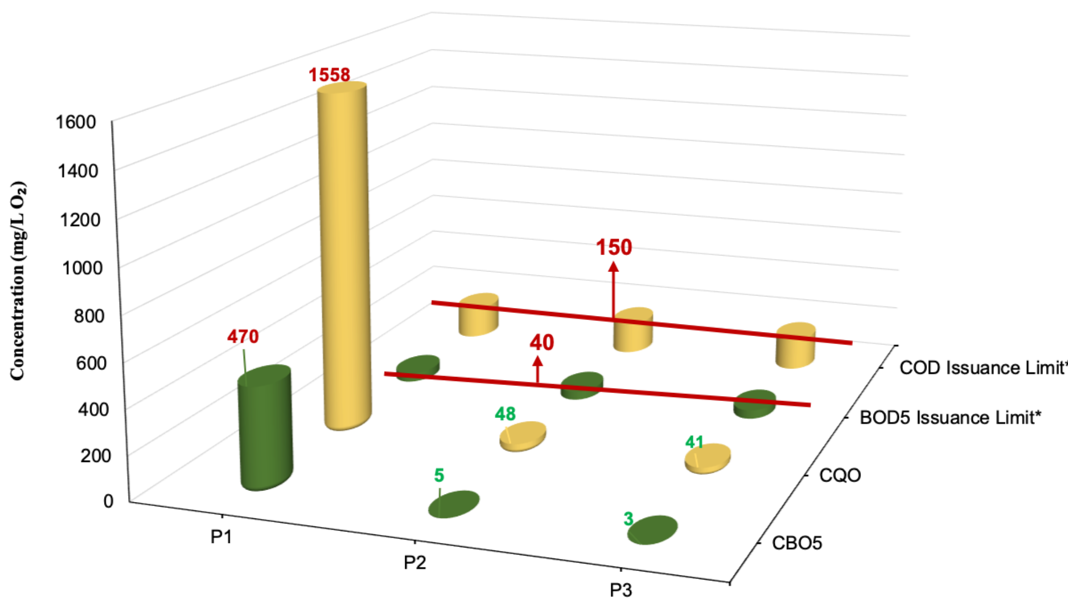

Figure 5. Values of CBO_5 and CQO in P1, P2, and P3.* Limits established by Angolan Presidential Decree No. 261/11(DecretoPresidencialn.o 261/11 de 06 de outubro, 2011).

Regarding the values of the two parameters at points P2 and P3, they were within the standards established by Angolan legislation. For point P2 (Figure 6), the results indicate that, under the analysed conditions, the treatment system of the WWTP at Quilomosso Centrality was able to eliminate a significant portion of the pollutant load; and, at the final discharge point (P3), the results were even lower than those observed at P2, demonstrating compliance with environmental standards. It is important to note that the samples were collected on a one-time basis rather than continuously, which limits the ability to confidently assert that the system maintains efficiency consistently, since the data refer to a specific moment in operation.

Figure6. Secondary clarifier of the Quilomoso WWTP.

Comparison of CBO and CQO results with international standards

Regarding the parameters studied, the treated effluent from the Quilomosso Wastewater Treatment Plant meets the standards set by many countries and regions worldwide. For example, the limits for BOD and COD in the European Union range from 15 to 40 mg/L and 75 to 150 mg/L, respectively. In Africa, BOD values range from 30 to 50 mg/L in Nigeria and 30 mg/L in Tanzania (Ogbu et al., 2025). In South Africa, the COD emission limit is 75 mg/L (Kachienga et al., 2025);in Benin, the limits for CBO and CQO are 25 mg/L and 125 mg/L, respectively(Clément Adjahouinou et al., 2025).

Efficiency of the QuilomossoWWTP (P2 and P3) and CBO/CQO ratio

The removal efficiency, as shown in Equation 1, measures the proportion of analyte removed during the treatment process and is expressed as a percentage (Inarmal& Moodley, 2024). The WWTP of Quilomosso demonstrated a very high efficiency (Table 1) in removing carbonaceous pollutants, COD, and BOD5 from the effluent at P2 and at the final discharge point (P3). From

P2 to P3, there is a slight increase in efficiency; however, the effluent is already deemed safe at P2 and, as corroborated by the flowchart shown in Figure 2, could be directly discharged into the Bolongonzo River after secondary treatment, with minimal risk of organic matter pollution.

Table 1. Efficiency of the Quilomosso WWTP (P2 and P3).

Samplingpoints	BOD_5 /mg.L^{-1}	COD/mg.L^{-1}	Efficiency in pollutantremoval	
			CBO_5	CQO
P1	470	1558		
P2	5	48	**98.94%**	**96.92%**
P3	3	4	**99.36%**	**97.37%**

Estimates of COD are generally higher than those of BOD_5 and vary depending on the specific water sample analysed. The BOD_5/COD ratio should not exceed 1.0, indicating the proportion of biodegradable organic matter in the wastewater. However, this ratio provides empirical rather than absolute results and is more helpful in comparing different samples than for quantifying specific pollutants. (Diwyanjalee et al., 2024). The biodegradability index (BDI) for P1 was 0.3017; for P2 and P3, it was 0.1042 and 0.0732, respectively. These results indicate that, in raw wastewater (P1), they fall within the values between 0.3 and 0.9, which are typical of domestic and municipal wastewater that can be treated or purified through biological processes with activated sludge (Diwyanjalee et al., 2024). And, after treatment at the wastewater treatment plant (P2 and P3), they show biodegradability indices below the ideal, indicating that they are non-biodegradable waters.

Normally, the biodegradability index values for surface waters, such as rivers, are ≤ 0.2 (in the Bolongonzo River – P3, BDI = 0.0732), because these waters are rich in nutrients, mineral salts, and other inorganic substances, and generally have a low content of biodegradable organic matter (Diwyanjalee et al., 2024).

These data reflect a high technical efficiency in removing organic load, demonstrating the good performance of the station even operating at only 5% of its nominal capacity. However, it is important to emphasise that the measurements were taken through spot sampling, which limits the ability to generalise the results. Therefore, continuous and systematic monitoring is essential to confirm effectiveness over time. Thus, although the data are encouraging, installing an analysis laboratory at the wastewater treatment plant and implementing periodic control routines are crucial measures to ensure a sustainable and fully verifiable treatment system performance.

Conclusion:-

This study technically evaluated the management of wastewater in the city of Uíge, focusing on the Quilomosso Centrality Treatment Station. The investigation was based on laboratory analyses and field observations, prioritizing the efficiency of the treatment system and the environmental impacts associated with discharging the treated effluent into the Bolongonzo River.

The results showed that the WWTP (Wastewater Treatment Plant) demonstrates high efficiency in removing pollutants, with 98.94% for BOD_5 and 96.92% for COD, meeting the limits set by Presidential Decree No. 261/11 of Angola. However, it is important to note that the data collection was limited and isolated, and not enough to confidently claim that the system maintains this performance continuously.

Another identified challenge is the absence of an analysis laboratory at the WWTP, which prevents on-site testing and limits the ability to respond to operational variations, compromising the quality control of the treated water.

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