# EVALUATION OF THE PHYSICO-CHEMICAL PROPERTIES OF EFFLUENTS FROM THE MOZAMBIQUE SUGAR COMPANY

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**Abstract**

Wastewater from the sugar industry has complex characteristics and is considered a challenge for environmental engineers in their search for treatment and reuse. The main objective of this study is to determine the physic-chemical characteristics of the wastewater from the Mozambique Sugar Plant. The choice is due to the large volumes of water (around 900 $m^3$ /h) that the sugar industry uses in its production processes, as well as the effluent management model that must be adopted. For this study, samples were taken over a six-month period, every two months, and physical and chemical parameters were analyzed. The results were compared with the regulations (Decree 18/2004) in use in Mozambique and the values estimated by the World Bank in the various articles. With the results obtained, it was possible to suggest the best method for treating these effluents in a more environmentally friendly way.

**Keywords:** Environmental management, sugar industries, wastewater, treatment systems.

## 1. Introduction

Wastewater from the sugar industry contains various compounds and needs to be treated chemically or biologically before being discharged into water bodies. The efficient reuse of wastewater produced by sugar industries is a point to be considered nowadays, with the aim of making the processes sustainable. Thus, interest in evaluating the characteristics of the effluents generated in the sugar industry has grown both in the fields of applied research and

in finding the best technological treatment alternative to meet the final destination of the effluent or the reuse of the water [1].

Wastewater from the food industry contains a high level of chemical and organic compounds, and in some cases can be up to 10 times higher than municipal wastewater. The discharge of effluents with a high load of organic compounds can create serious environmental problems. This is why, before these effluents are discharged into the environment, they must be cleaned first and properly[2,3,4,5]. Many studies report that large quantities of pollutants in sugar industry wastewater, most notably biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total dissolved solids (TDS) are always above the recommended environmental discharge standards [1,2,3] The sugar industry is basically seasonal in nature and only operates for 150 to 210 days a year (November to May). A significantly large volume of waste is generated during sugar manufacture and contains a large amount of pollutant load, especially in terms of suspended solids, organic matter and pressed sludge, bagasse and atmospheric pollutants. Various chemicals are used in the sugar industry mainly for coagulating impurities and refining end products. $Ca(OH)_2$ is used to clarify and increase the pH of juices. A small amount of $H_3$ $PO_4$ is added before fining to improve clarification[1]. It is in this sense that we are interested in understanding the characteristics of the effluents from Açucareira de Moçambique and the conditions in which they are discharged into the environment, with a view to finding more appropriate and sustainable measures.

In environmental engineering and more specifically in effluent treatment technologies, the concentration of organic matter in the effluent is measured using two main analytical parameters, biochemical oxygen demand (BOD) and chemical oxygen demand (COD). BOD shows the amount of oxygen required to stabilise carbonaceous organic matter through biochemical processes, indirectly indicating the amount of biodegradable organic carbon, while COD measures the consumption of oxygen due to the chemical oxidation of organic matter, indirectly measuring the content of organic matter present. [10]

The choice of treatment technologies for any effluent depends on the COD/BOD ratio, according to studies[13] . Thus, according to

him: Low COD/BOD ratio (<2.5): the biodegradable fraction is high, and the use of biological treatment is recommended; Intermediate COD/BOD ratio (from 2.5 to 4.0): the biodegradable fraction is not high, and it is recommended to carry out treatability tests to validate the use of biological treatment. Biological treatment refers to secondary level treatment [10; 12];High COD/BOD ratio (>4.0): the inert (non-biodegradable) fraction present in the effluent is high, it is not recommended to use a biological system, and the potential for using a chemical treatment system should be assessed; Low COD/BOD ratio (4.0): the inert (non-biodegradable) fraction present in the effluent is high, the use of a biological system is not recommended, and the potential for using a chemical treatment system should be evaluated.[13]

To analyse biodegradability, a minimum BOD:N:P ratio of 100:5:1 is used for aerobic processes and a COD:N:P ratio of at least 350:7:1 for anaerobic processes, as suggested by[13]. Some authors, such as those mentioned in Table 1, have carried out studies in the sugar industry and show some characteristic results. The table shows that, in general, most of the results for the treatment of industrial effluents are in the range of primary and secondary treatments[11; 12; 13].

| Parameters | [1] | [8] | [11] |
|---|---|---|---|
| Temperature($^0$ C) | 40 | 29.3-44.3 | 24.3 |
| pH | 5.5 | 6.7-8.4 | 4.0 |
| Turbidity (NTU) | | | 621 |
| BOD (mg/l) | 970 | 654.4-1968.5 | 431.9 |
| COD (mg/l) | 3682 | 1100.3-2148.9 | 1536.8 |
| Conductivity ($\mu S/cm$) | 2230 | 540.3-925.9 | 534 |
| Phosphate (mg/l) | 5.9 | 1-19 | 15 |
| Nitrogen (mg/l) | | 11.9-40.6 | 30 |

Table 1. Effluent Parameter Values from Some Authors

## 2. Materials and Methods

### 2.1 Description of the Sampling Sites

The Mozambique Sugar Factory (Mafambisse) is a sugar industry

located in the district of Dondo, south of the city of Beira, 1 kilometer from National Road 6 (EN6). The sugar plant has been run by the company Tongaat Hulett since 1996. Tongaat Hulett is a South African company that operates in the sugar business in several South African countries: Mozambique, Botswana, South Africa, Swaziland, Zimbabwe and Namibia. Normally, the sugar industry is made up of two productive sectors: the agricultural sector, i.e. the cane field, and the processing sector (Factory) [14-19].

In Mozambique, Tongaat Hulett has factories in Xinavane, Maputo province, and in the administrative post of Mafambisse, Dondo district, Sofala province, with the mission of promoting services and products derived from sugar cane, making them ever better, seeking customer satisfaction and the development of the country, while always caring for and protecting the environment.[6,7]

However, they use a large volume of water, ranging from [900$m^3$ to 1000$m^3$ ]/hour extracted from the River Púngue to cool machines, bearings, mills, boilers and in some cases even in the Process area and other activities that use water and even for human consumption.

### 2.2 Sample Collection and Analysis

The sugarcane transformation process is highly complex, generating significant quantities of wastewater comprising liquid and solid discharges from the processing, handling and transformation of sugarcane. These discharges result from cooling, heating, extraction and reaction processes, as well as the washing of by-products and the control of other rejected specification by-products. The quantities and qualities of these discharges are highly variable. As the water passes through the chambers and tanks from extraction to sugar crystallization, its pollutant load in terms of organic matter and various pollutants increases significantly. Approximately 75 per cent of the total volume of effluents discharged by sugar cane industries is due to sugar cane washing, which also includes washing water from tanks containing processing residues. On the other hand, the defibration and milling processes, which aim to extract the juice, result in solid waste: bagasse, which is made up of fibre. [8]

All the effluent samples were collected and analyzed on the same day, according to the methodology described in Standard Methods

for the Examination of Water and Wastewater (23rd Edition.2017) [20-24]. For these analyses, the samples were collected in 500 ml Pet bottles using a handmade collector. After collection, the bottles with the samples were duly identified and transported in an insulated box to the Microbiology and Biochemistry laboratories of the Department of Industrial Process Engineering at Zambezi University for analyses. The collection process was carried out throughout the study period of 6 months, at intervals of every 2 months, in the sections of the pumps (total effluent from the factory), boiler outlet and total effluent from the workshops. As shown in figure 1 below.

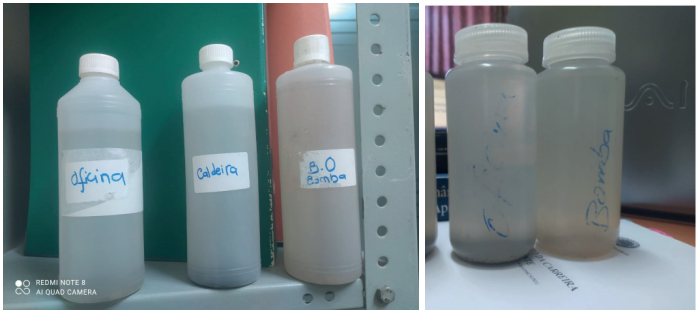


Figure 1 Photo of effluent samples taken from workshops, pumps and boilers. (Author source)

The instantaneous sampling technique in accordance with the standards was used to measure physicochemical parameters (temperature and pH) at the sites. In all cases, the wastewater samples were collected in pre-cleaned, acid-washed plastic bottles and stored in a refrigerator at 4°C until they were used for analyses. Finally, the laboratory analyses of the wastewater samples that were carried out according to standard methods in our local laboratories. Among the physical-chemical parameters of the sugar industry's wastewater, pH and Temperature were measured immediately on site, while the other physical-chemical parameters, such as Total Solids (ST), Suspended Solids (TSS), BOD, COD, chloride and sulphate tests, Turbidity, Alkalinity, Density and Conductivity, were analysed in our laboratories here at Zambezi University in Mozambique. In most sugar-producing countries, there

are already liquid effluent control standards that set a limit on the amount of organics, between 15 and 60 mg/L of BOD (Biochemical Oxygen Demand), with the exception of India, where the limit is 100 mg/L (Purchase, 1996). In these countries, effluent treatment is carried out in anaerobic or aerobic lagoons [9].

| Parameters | Pump | Boilers | Opficinas | Decree 18/2004 |
|---|---|---|---|---|
| Temperature($^0$ C) | 45 | 50 | 40 | < =24 |
| PH | 6.34 | 8.13 | 6.96 | 6-9 |
| Hardness (mg/l) | 240.63 | 490.20 | 177.13 | |
| Alkalinity (mg/l) | 187.00 | 215.00 | 138.33 | |
| Chlorides (ml/g) | 105.60 | 172.63 | 81.43 | |
| TDS(mg/l) | 1392.00 | 1174.67 | 1137.00 | |
| TSS(mg/l) | 17.33 | 25.67 | 22.00 | 50 |
| Turbidity (NTU) | 9.15 | 11.16 | 15.03 | |
| BOD(m/l) | 731.67 | 628.00 | 675.00 | 50 |
| COD(m/l) | 1048.67 | 991.33 | 1351.00 | 250 |
| Conductivity (S/cm) | 2.49 | 1.96 | 7.83 | |
| Phosphate (mg/l) | 11.91 | 16.22 | 16.23 | 2 |
| Nitrogen (mg/l) | 14.11 | 10.58 | 11.39 | 10 |

Table 2. Values of the Physico-Chemical Parameters of the Mozambique sugar plantation

## 3. Results

The physicochemical properties of the wastewater from the sugar industry studied are well above the limit values of the legislation in use (Decree 18/2004), although some values are not used in the document [25-27]. Thus, according to the data obtained and the volumes of effluent generated (900-1000 $m^3$ /h), it would be best to use aerobic lagoons, because with a residence time of more than 120 hours or up to 7 days, the temperature is guaranteed to be reduced to ambient values and aerobic processes are allowed to occur, which could reduce the contaminant load, according to references [12,13]. The results of the COD/BOD ratio for the present study in the different study areas range from 1.48 to 2.0, respectively for the pump, boiler and workshop sectors, with the aver-

age ratio being 2.0, indicating that for this range the suggested treatment technology according to [13] is secondary biological in nature.In the meantime, this technology will be analysed in detail using technical parameters such as effluent flow and the area available for disposal and final treatment. According to the results of the Total Nitrogen and Total Phosphorus content, which are essential in the degradation of the effluent, as shown.

## 4. Conclusions

The study of the physical and chemical parameters of the effluents from the Mozambican sugar mill showed that the pH value was within the standards established by the regulation on environmental quality standards and effluent emissions for the sugar industry (Decree 18/2004). According to Mozambican legislation, the COD/BOD ratio is 5. In this study, the ratio ranged from 1.4 to 2.0, well below the established limits, which indicates the high biodegradability of the effluent load. The suggested technology is therefore biological treatment.

## References

1. Pradeep K, Poddar; Omprakash Sahu. Quality and management of wastewater in sugar industry. Water Sci 2 November 2014.

2. Ana Marszalek and Ewa Puszczalo. Effect of Photooxidation on nanofiltration membrane fouling during wastewater treatment from the confectionary Industry. Water 2020,12,793,doi:3390/w12030793/ 12 march

3. Abou-Elela, S.I.; Nasr, F.A.; El-Shafai, S.A. Wastewater management in small- and medium-size enterprises: Case studies. Environmentalist 2008, 28, 289-296 [Google Scholar] [CrossRef]

4. Ozgun, H.; Karagul, N.; Dereli, R.K.; Ersahin, M.E.; Coskuner, T.; Ciftci, D.I.; Ozturk, I.; Altinbas, M. Confectionery industry: A case study on treatability-based effluent characterisation and treatment system performance. Water Sci. Technol. 2012, 66, 15-20 [Google Scholar] [CrossRef] [PubMed]

5. Sahu, O.P.; Chaudhari, P.K. Electrochemical treatment of sugar industry wastewater: COD and colour removal. J. Electroanal. Chem. 2015, 739, 122-129 [Google Scholar] [CrossRef]

6. Yotamo, A. F. D., Energy Balance of Boilers and Steam Lines, Monograph, 2009.

7. Marques, António E.C. Efficient Steam Generation from Bagasse, Internship Report, December 2014.

8. Abdoul Wahab Nouhou Moussa; Boukary Sawadogo; Yacouba Konate; Sayon dit Sadio Sidibe; and Marc Heran. Critical State of the Art of Sugarcane Industry Wastewater Treatment Technologies and Perspectives for Sustainability. Membranes 2023, 13, 709. https://doi.org/10.3390/membranes13080709.

9. José M. F. de Andrade; Kátia M. Diniz. Environmental Impacts of the Sugarcane Agroindustry: Subsidies for Management. Piracicaba September 2007

10. Nilton Bruno Silva Batista, André Aguiar, Study of physicochemical parameters and their correlations for dairy effluents in the state of Minas Gerais. XXII Latin American Scientific Initiation Meeting, XVIII Latin American Postgraduate Meeting and VIII Teaching Initiation Meeting - University of Vale do Paraíba, 2018;

11. Apoorva D, Chandrashekar B. Treatment of Sugar Industry Wastewater by Adsorption method, International Research Journal of Modernisation in Engineering Technology and Science. Volume:04/Issue:08/August-2022;

12. Guirrima, P.V.M; Chirinza,N.P.; Grande,S.C; Mendieta Pino, C. A; León Zerpa,F; Pérez Báez,S.O; Martín, A. R. Tratamiento de efluentes domésticos mediante métodos bioflitro sostenibles. X Jornadas Iberoamericanas de Innovación Educativa en el ámbito de las TIC y las TAC Las Palmas de Gran Canaria, 16 and 17 November 2023.

13. Matos,M.P.Effect of Binomial Time-Temperature of sample incubation on Biochemical Oxygen Demand diffusion of wastewater. Master's dissertation. Federal University of Viçosa, Minas Gerais 2012.

14. D. K. Amenorfenyo et al, «Microalgae brewery wastewater treatment: Potentials, benefits and the challenges,» Int J Environ Res Public Health, vol. 16, no. 11, Jun. 2019, doi: 10.3390/ijerph16111910.

15. Z. Luo, D. Xu, Y. Ma, and Q. Cheng, «Experimental study on co-firing of coal and brewery wastewater sludge,» Applied Sciences (Switzerland), vol. 10, no. 21, pp. 1-11, Nov. 2020, doi: 10.3390/app10217589.

16. M. Vítězová, A. Kohoutová, T. Vítěz, N. Hanišáková, and I. Kushkevych, «Methanogenic microorganisms in industrial wastewater anaerobic treatment,» Processes, vol. 8, no. 12. MDPI AG, pp. 1-27, Dec. 01, 2020. doi: 10.3390/pr8121546.

17. K. P. Shabangu, B. F. Bakare, and J. K. Bwapwa, «The Treatment Effect of Chemical Coagulation Process in South African Brewery Wastewater: Comparison of Polyamine and Aluminum-Chlorohydrate coagulants,» Water (Switzerland), vol. 14, no. 16, Aug. 2022, doi: 10.3390/w14162495.

18. A. Karlović, A. Jurić, N. Ćorić, K. Habschied, V. Krstanović, and K. Mastanjević, «By-products in the malting and brewing industries-re-usage possibilities,» Fermentation, vol. 6, no. 3. MDPI AG, 2020. doi: 10.3390/FERMENTATION6030082.

19. P. Thanekar and P. Gogate, «Application of hydrodynamic cavitation reactors for treatment of wastewater containing organic pollutants: Intensification using hybrid approaches,» Fluids, vol. 3, no. 4. MDPI AG, Dec. 01, 2018. doi: 10.3390/fluids3040098.

20. S. M. Khumalo, B. F. Bakare, S. Rathilal, and E. K. Tetteh, «Characterisation of South African Brewery Wastewater: Oxidation-Reduction Potential Variation,» Water (Switzerland), vol. 14, no. 10, May 2022, doi: 10.3390/w14101604.

21. G. Salbitani and S. Carfagna, «Ammonium utilisation in microalgae: A sustainable method for wastewater treatment,» Sustainability (Switzerland), vol. 13, no. 2. MDPI, pp. 1-17, Jan. 02, 2021. doi: 10.3390/su13020956.

22. A. Chakraborty, A. Pal, and B. B. Saha, «A Critical Review of the Removal of Radionuclides from Wastewater Employing Activated Carbon as an Adsorbent,» Materials, vol. 15, no. 24. MDPI, Dec. 01, 2022. doi: 10.3390/ma15248818.

23. C. A. Mendieta-Pino, T. Garcia-Ramirez, A. Ramos-Martin, and S. O. Perez-Baez, «Experience of Application of Natural Treatment Systems for Wastewater (NTSW) in Livestock Farms in Canary Islands,» Water Journal (Switzerland), vol. 14, no. 14, Jul.

2022, Editorial MDPI doi: 10.3390/w14142279.

24. S. M. Khumalo, B. F. Bakare, S. Rathilal, and E. K. Tetteh, «Characterisation of South African Brewery Wastewater: Oxidation-Reduction Potential Variation,» Water (Switzerland), vol. 14, no. 10, May 2022, doi: 10.3390/w14101604.

25. A. G. Rao, T. S. K. Reddy, S. S. Prakash, J. Vanajakshi, J. Joseph, and P. N. Sarma, «pH regulation of alkaline wastewater with carbon dioxide: A case study of treatment of brewery wastewater in UASB reactor coupled with absorber,» Bioresour Technol, vol. 98, no. 11, pp. 2131-2136, Aug. 2007, doi: 10.1016/j.biortech.2006.08.011.

26. F. Younas et al, «Current and emerging adsorbent technologies for wastewater treatment: Trends, limitations, and environmental implications,» Water (Switzerland), vol. 13, no. 2. MDPI AG, Jan. 02, 2021. doi: 10.3390/w13020215.

27. G. G. Santonja, P. Karlis, K. R. Stubdrup, and T. Brinkmann, «Best Available Techniques (BAT) Reference Document for the Food, Drink and Milk Industries,» 2010.

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