NEW METHODOLOGY FOR CHARACTERISATION OF WASTEWATER IN THE BREWING INDUSTRY.

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Abstract

This study introduces a new methodology for characterisation of wastewater in the brewing industry. Wastewater from the brewery industry has complex characteristics and is a challenge for environmental engineers in their search for treatment and reuse. The main objective of this study is to compare the physicochemical characteristics of wastewater from the brewery industry in Mozambique and other African countries. The choice is due to the large volumes of water used by the brewery industry in its production processes, as well as the effluent management model that must be adopted. For this study, samples were collected, and their physical and chemical parameters analysed. The results were compared with different breweries industries in other countries in the area, the legislation in force in Mozambique and the values estimated in the different articles considered in the literature. With the results obtained, it was possible to characterise the wastewater from the brewery industry in Mozambique to find the best method of treating these effluents in a more environmentally friendly way.

Keywords: Environmental management, brewery industries, wastewater, treatment systems.

1. INTRODUCTION

In recent years, with the development of the global economy, energy shortages and environmental pollution have become two major issues facing humanity. The development of efficient and

clean combustion of fossil energy, the comprehensive utilisation of renewable fuels and the reduction of environmental pollution have become unavoidable requirements for sustainable social development [1], [2]. Water pollution is a major problem facing societies, which have been degrading the environment at an ever-increasing rate for several decades [3], [4]. Industrial wastewater constitutes an environmental pressure, even though this water is, in some cases, collected by a local sewage network, treated in an urban wastewater treatment plant (WWTP) and subsequently released into the environment [3]. It should be noted that the environmental degradation caused by the discharge of industrial effluents has increased sharply in Africa and around the world [4]. Mozambican legislation (Law No. 18/91) in its Chapter IV, Section I, Article 51, establishes that water contamination consists of the action and effect of introducing materials, forms of energy or the creation of conditions that, directly or indirectly, imply a detrimental alteration of its quality in relation to subsequent uses or its ecological function. The brewing industries, despite being a vital part of the economy of the producing country, consume large volumes of water during the production processes, and subsequently release around 70 per cent of it as wastewater [1]. The production of 1 litre of beer consumes 10 litres of water and around 7 litres end up as waste water. The amount of water used can fall below the figures mentioned in larger breweries or if advanced technology is used (2.2-3.3 hL of water for 1 hL of beer), but the disposal of brewery wastewater is still a major challenge [5]. The brewery wastewater component, such as surplus yeast grains, produced in two main stages of beer production (brewing and packaging), are the main contributors to environmental pollution when mixed with effluent [3], [4], [6]In terms of composition, brewery wastewater has high chemical oxygen demand (COD), along with 5-day biochemical oxygen demand, total solids, nitrogen and phosphorus pollutants, volatile fatty acids, etc. However, nitrogen and phosphorus concentrations depend on the type of chemicals that are used in the brewery, as well as the amount of yeast used in the effluent [7]. However, studies show that this effluent is dangerous when exposed to the environment without prior treatment. This phenomenon points to the need to find treatment mechanisms that lead not only to the reduction of this waste, but also to the return of

purer water to the environment, combined with the reuse of water in various applications [8], [9]. The main environmental concerns raised by brewery operations include water consumption, wastewater, solid waste and by-product generation, energy use and atmospheric emissions. This phenomenon leads to environmental problems such as water scarcity, excessive growth of undesirable microbes that cause loss of aquatic life forms and health-related problems in the communities around the discharge areas [1], [8], [9]. As a way of minimising the pollutant load, there are two types of wastewater treatment systems, namely conventional and non-conventional treatment systems [10]. In the non-conventional system we can find anaerobic digestion [1], [10]. Systematic research and a deeper understanding of the anaerobic process have led to anaerobic digestion (AD), a biological process in which organic matter is converted into CH_4 e CO_2 has become a more attractive technology for wastewater treatment due to its low capital and operating costs compared to other technologies available in recent decades [3], [11]. Today, anaerobic techniques are generally used in industries with a high level of soluble and easily biodegradable organic material[3]. This work aims to provide new knowledge about the characteristics of the wastewater generated in a brewery in Mozambique. However, characterisation will help in the development and design of an optimal wastewater treatment system capable of significantly reducing pollutants.

2. MATERIALS AND METHODS

The process of taking samples of the brewery's wastewater was based on the identification of a converging point (INLET SUMP 100-TK-101 tank) where the water is found in its raw state, originating from the various stages and activities, most notably the manufacturing, filling and logistics processes [15-19]. Samples were taken over several days in order to provide better characterisation, and the same samples were analysed in the laboratory, followed by analyses of the main standard parameters, namely: pH, Temperature, Alkalinity, Conductivity, TDS, Turbidity, Phosphate, Nitrogen, BOD and COD. The analysis of pH, conductivity and TDS was based on the use of the HQ40d equipment, and the temperature and alkalinity parameters were analysed using the

titration technique [20-27]. The 2100 turbidimeter was used to analyse turbidity and finally the parameters Phosphate, Nitrogen, BOD and COD were analysed using the DR6000 equipment. The water from the various activities flows into a tank made up of a grid to remove coarse solids, after which it passes through a filter tank to remove some solids whose granulometry does not allow them to pass through the pores. A container is attached to this filter tank to deposit the solids retained in the filter. The system has several automatic control valves, one of which controls the level of pH in the water after the filtration process, and when it is high it has a tank called a calamity tank which corrects the P^H by adding a specific acid to stabilise it. In addition to the tanks, there is a later tank called the lung tank, followed by two tanks with anaerobic bacteria (emergency tank and DACS reactor) where anaerobic biological treatment takes place. The system also has two tanks with aerobic bacteria in sequence (MBBR1 and MBBR2), a decanter with a bottom for removing sludge. After sedimentation there is a sand filter and a chlorine dosing tank.

3. DISCUSSION

Table 2 presents a comparative numerical assessment of the data obtained from the different laboratory analyses of the samples taken at the Mozambican brewery for the present study and compared with the results obtained in past studies by different authors.

Parameter	Sample Analisys	[5]	[7]
P^H	5.1 – 6.4	3- 12	4.4. – 12.2
Temperature (°C)	18 – 20	18- 40	25.3 - 37
Alkalinity (mg/l)	240 – 265	_	_
Condutivity (µS/cm)	2120 – 3480	_	1893 - 6017
TDS (mg/l)	2335 – 3246	2020 - 5940	1043 - 2572
Turbidity (NTU)	53.42 – 349.92	187 - 2000	303 - 1039
Phosphate (mg/l)	15.12 – 37.22	10 - 50	_
Nitrogen (mg/l)	22.03 – 35.09	25 - 80	13.7 - 106
DBO (mg/l)	1490 – 3241	1200 - 3600	_
DQO (mg/l)	2670 - 3798	2000 - 6000	3447 - 11813

Table 2: Comparative data for the different parameters.

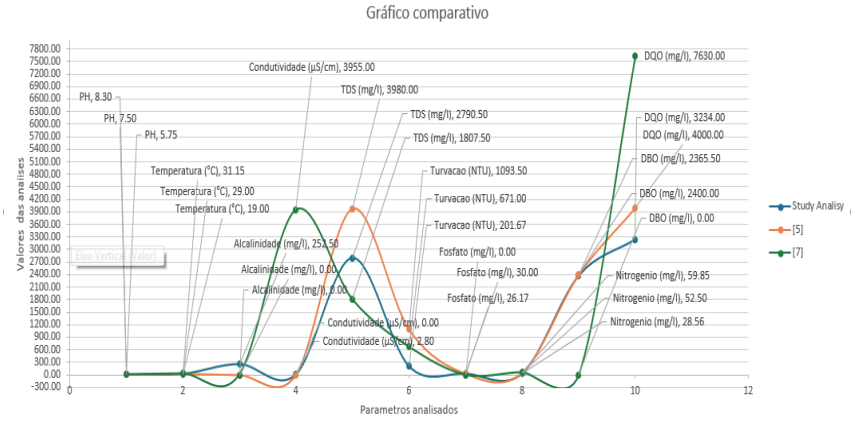
According to the laboratory results of the different samples taken at the Mozambican brewery, the effluent shows a varied acidic level with a weak tendency, with reference to the pH values. The characteristic weak acidic variation of the wastewater from the Mozambican brewery originates from the use of strong and moderate acids (nitric and phosphoric acid) in the cleaning and sanitising process and is buffered from the drainage of a strong base (caustic soda) used in the filling process.

Regarding the alkalinity parameter, it should be emphasised that it represents the quantitative capacity of the acid to be absorbed without altering the pH. According to the sample data relating to this parameter, it shows a high buffering capacity and is less affected when something acidic is added. On the other hand, it resists changing the P^H when a small amount of a strong acid or base is added.

When it comes to conductivity, the tributary analysed has a lower dissolved salt content, although this is directly proportional to its conductivity. About dissolved solids, the values obtained indicate a high rate. The wastewater has a high concentration of Biochemical Oxygen Demand (BOD) due to the presence of carbohydrates and proteins used in beer production. In this study it has been compared the wastewater from the brewing industries of Mozambique to other references [5] and [7]. It is shown the COD analysed in Mozambique is in the same range of the others, a bit lower than them. BOD is also in the same Intervale of the others. Turbidity is lower than in the other references [5, 7], but still in the range. In the case of Phosphate and Niitrogen, they are also in the interval of the brewing industries waste water. COD Indicates the amount of oxygen required to decompose organic matter through chemical oxidation [15], [16]. However, the comparison with [5] and [7] shows a linearity in the values due to the standardisation of the raw materials used and the work project. The main source of turbidity in wastewater is the presence of solid particles in the medium, which can be an indicator of pollutants and also make it difficult to visualise the effluent [17], [18], [19]. The water analysed in the project has a low turbidity content compared to [5] and [7], which shows that there is little emission of solid particles in the Mozambican brewery.Phosphate is an essential compound for the development of processes of biological origin, but in excessive quantities in ef-

fluents it can cause the phenomenon of eutrophication, where there is excessive growth of algae and thus a reduction in the oxygen necessary for the survival of aquatic beings [19], [20].

Graph 1: Comparative evaluation of the average data for the different parameters



It should be noted that the number found in the project shows a high value compared to [5], raising concern in order to minimise the situation of lack of survival and forcing the repair of regulatory standards for the minimum parameters necessary for wastewater to be allowed to leak into a receiving water body.Nitrogen manifests an indirect characterisation of proteins present in wastewater, and wastewater from a brewery will always contain the substance in question due to the characteristics of the main raw materials used in the brewing process [12], [19]. On average, the value found in the project is low compared to [5] and [7]. In all cases, the values obtained by the different authors and the current study are consistent. There is no great discrepancy in the values, which means that in terms of the work project and the products used, there is a close approximation. In this paper, after studying all the data taken and comparing with the wastewater from the brewing industries of Mozambique and other references [5] and [7], it is shown the following:

- COD analysed in Mozambique is in the same range as the other references, a bit lower than them.

- BOD is also in the same range as the others.
- Turbidity is lower than in the other references [5, 7], but still in the range.
- Phosphate and Nitrogen, they are also in the interval of the brewing industries wastewater.

REFERENCES

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

6. 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.

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

8. G. Salbitani and S. Carfagna, "Ammonium utilization 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.

9. 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.

10. 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 (Switzerland)*, vol. 14, no. 14, Jul. 2022, doi: 10.3390/w14142279.

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

12. 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.

13. 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.

14. 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.

15. Q. Wang *et al.*, "Novel Approaches for the Solid-Phase Synthesis of Dihydroquinazoline-2(1H)-One Derivatives and Biological Evaluation as Potential Anticancer Agents," *Molecules*, vol. 27, no. 23, Dec. 2022, doi: 10.3390/molecules27238577.

16. J. Ramsuroop, L. Gutu, W. B. Ayinde, M. Basitere, and M. S. Manono, "A Review of Biological Processes for Dairy Wastewater Treatment and the Effect of Physical Parameters Which Affect Their Efficiency," *Water (Basel)*, vol. 16, no. 4, p. 537, Feb. 2024, doi: 10.3390/w16040537.

17. I. Naz, I. Ahmad, R. W. Aslam, A. Quddoos, and A. Yaseen, "Integrated Assessment and Geostatistical Evaluation of Groundwater Quality through Water Quality Indices," *Water (Basel)*, vol. 16, no. 1, p. 63, Dec. 2023, doi: 10.3390/w16010063.

18. H. M. Saleh, S. Albukhaty, G. M. Sulaiman, and M. M. Abomughaid, "Design, Preparation, and Characterization of Polycaprolactone–Chitosan Nanofibers via Electrospinning Techniques for Efficient Methylene Blue Removal from Aqueous Solutions," *Journal of Composites Science*, vol. 8, no. 2, p. 68, Feb. 2024, doi: 10.3390/jcs8020068.

19. C. M. Otálora González, M. Felix, C. Bengoechea, S. Flores, and L. N. Gerschenson, "Development and Characterization of Edible Films Based on Cassava Starch Modified by Corona Treatment," *Foods*, vol. 13, no. 3, p. 468, Feb. 2024, doi: 10.3390/foods13030468.

20. P. Sanciolo, A. K. Sharma, D. Navaratna, and S. Muthukumaran, "Stormwater Treatment Using Natural and Engineered Options in an Urban Growth Area: A Case Study in the West of Melbourne," *Water (Switzerland)*, vol. 15, no. 23, Dec. 2023, doi: 10.3390/w15234047.