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Evaluación de las propiedades físicoquímicas de los efluentes de la Mozambique Sugar Company

Evaluation of the physicochemical properties of effluents from the Mozambique Sugar Company

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Resumen: Las aguas residuales de las industrias azucareras se consideran un desafío para los ingenieros ambientales en la búsqueda de tratamientos y reutilización. El principal objetivo de este estudio es determinar las características fisicoquímicas de las aguas residuales de la Açucareira de Moçambique. La elección se debe a los volúmenes de agua (alrededor de 900 m3/h) que utiliza la industria azucarera en sus procesos productivos, así como al modelo de gestión de efluentes que debe adoptarse. Para el presente estudio, se recolectaron muestras durante un período de seis meses, cada dos meses, analizando parámetros físicos y químicos. Los resultados fueron comparados con los del reglamento (Decreto nº 18/2004) vigente en Mozambique y los valores estimados por el Banco Mundial presentes en los diferentes artículos. Debido a los resultados obtenidos, se ha podido confirmar el método más adecuado para evaluar el tratamiento de estos efluentes de una forma más respetuosa con el medio ambiente.

Palabras clave: Gestión ambiental; industria azucarera; aguas residuales; sistemas de tratamiento.

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 m3 /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 environmen-tally friendly way.

Keywords: Environmental management; sugar industries; wastewater; treatment systems.

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I. 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 biochemi-cal 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 basi-cally seasonal in nature and only operates for 150 to 210 days a year (November to May) [4]. 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 im-purities and refining end products. $Ca(OH)_2$ is used to clarify and increase the pH of juices. A small amount of H_3PO_4 is added before fining to improve clarification [1]. We are interested in the understanding of 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 [9, 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 [11, 13, 14].

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 charac-teristic 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]. The main objective of this study is to determine the physic-chemical characteristics of the wastewater from the Mozambique Sugar Plant.

Table 1. Effluent parameter values from some authors

Parameters	[1]	[8]	[11]
Temperature(C)	40	29.3-44.3	24.3
pH	5.5	6.7-8.4	4.0
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

Note: self-made source.

II. Materials and Methods

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, 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 [900m3 to 1000m3]/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.

Figure 1**.** Localization of sugar cane factory in mafambisse

Note: Google Earth source.

Materials

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% 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].

Methods

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 2 below.

Figure 2**.** Photo of effluent samples taken from workshops, pumps and boilers

Note: author source.

Table 2.

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

Note: self-made source.

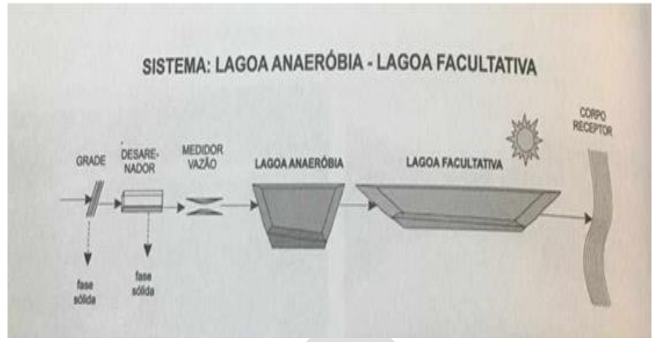
III. Results

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. This technology will be analysed in detail using technical parameters such as effluent flow and the area available for disposal and final treatment.

Proposed Representation

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). 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.

Figure 3**.** Flowchart of an anaerobic lagoon system followed by facultative lagoons [28]



Note: *Tratamento biológico de Efluentes industriais.*

IV. Discussion

The analysed effluent treatment system consists of a pre-treatment consisting of screens, a grease separator, followed by the actual treatment by means of stabilisation ponds.
In the stabilisation ponds the effluent load is gradually degraded until it is discharged into rivers in an environmentally friendly manner.

V. 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.

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