EVALUATION OF THE PHYSICO-CHEMICAL PROPERTIES OF EFLUENTS FROM THE MOZAMBIQUE SUGAR COMPANY. A PROPOSAL FOR EFFLUENT TREATMENT

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ABSTRACT:

Wastewater from the sugar industry presents complex characteristics and is considered a chal- lenge for environmental engineers in their quest for treatment and reuse. The main objective of this study is to determine the physico-chemical characteristics of the wastewater from the Mozambique Sugar Mill. 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 to be adopted. For this study, samples were taken over a period of six months, every two months, and physical and chemical parameters were analysed. The results were compared with the regulations (Decree 18/2004) in force in Mozambique and with the values estimated by the World Bank in the various articles. The novelty of this research and the purpose is to suggest the best method to treat these effluents in a more environmentally friendly way. With the results obtained, it was possible to do so in most of the sugar producing countries that have liquid effluent control standards with limitation in the number of organics between 15 and 60 mg/L BOD.

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

RESUMEN:

Las aguas residuales de la industria azucarera presentan características complejas y se consideran un reto para los ingenieros medioambientales en su búsqueda de tratamiento y reutilización. El objetivo principal de este estudio es determinar las características físico-químicas de las aguas residuales de la Central Azucarera de Mozambique. La elección se debe a los grandes volúmenes de agua (alrededor de 900 m3 /h) que la industria azucarera utiliza en sus procesos de producción, así como al modelo de gestión de efluentes que se debe adoptar. Para este estudio, se tomaron muestras durante un período de seis meses, cada dos meses, y se analizaron parámetros físicos y químicos. Los resultados se compararon con la normativa (Decreto 18/2004) vigente en Mozambique y con los valores estimados por el Banco Mundial en los distintos artículos. La novedad de esta investigación y el propósito es sugerir el mejor método para tratar estos efluentes de forma más respetuosa con el medio ambiente. Con los resultados obtenidos, fue posible hacerlo en la mayoría de los países productores de azúcar que tienen normas de control de efluentes líquidos con limitación en el número de orgánicos entre 15 y 60 mg/L de DBO.

Palabras clave: Gestión medioambiental, industrias azucareras, aguas residuales, sistemas de tratamiento.

1. - INTRODUCTION

Wastewater from the sugar industry contains various compounds that need to be treated chemically or biologically before being discharged into water bodies. The efficient reuse of wastewater produ- ced by the sugar industries is an issue to be considered nowadays, with the aim of sustainability. Thus, the evaluation of the characteristics of the effluents generated in the sugar industry is of growing interest both in the field of applied research and in the search for the best technological treatment alternative to meet the final destination of the effluent or the reuse of the water to be explained in the following topics[1].

Wastewater from the food industry contains a high level of organic compounds, in some cases up to 10 times higher than municipal wastewater. The discharge of effluents with a high load of orga- nic compounds creates serious environmental problems. Therefore, these effluents must be pro- perly cleaned before discharge into the environment [2,3,4,5]. Numerous studies have pointed out that wastewater from the sugar industry can contain high levels of pollutants, such as biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total dissolved solids (TDS), which can often exceed the recommended environmental standards for discharge [1, 2, 3]. It should be noted that the sugar industry is seasonal and only operates between 150 and 210 days per year (November to May). Various chemicals are used in the sugar industry, mainly to coagulate impu- rities and refine the final products. $Ca(OH)_2$ is used to clarify and increase the pH of the juices. Before clarification, a small amount of H_3PO_4 is added to improve

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clarification [1]. Here we investigate the characteristics of the effluents from Açucareira de Moçambique and the conditions under which they are discharged into the environment, in order to diagnose more appropriate and sustainable measures.

In environmental engineering, and more specifically in effluent treatment technologies, the con- centration of organic matter in the effluent is measured using two main analytical parameters: bio- chemical 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. COD is the maximum organic matter that can be oxidised, while BOD is the matter that can be used by living organisms [10].

The novelty of this research and the purpose is to suggest the best method to treat these effluents in the most environmentally friendly way. The choice of treatment technologies for any effluent depends on the COD/BOD ratio, according to studies[13]. Thus, according to Matos, M.P.: Low COD/BOD ratio (<2.5): the biodegradable fraction is high and the use of biological treatment is recommended. For an intermediate COD/BOD ratio (between 2.5 and 4.0), treatability tests are suggested to confirm the suitability of biological treatment due to the relatively low biodegradable fraction. The process known as biological treatment is normally used for secondary level treatment [10; 12]. In cases where the COD/BOD ratio is high (>4.0), it may not be advisable to use a biolo- gical system, and it may be necessary to evaluate the possibility of using a chemical treatment system instead. Similarly, if the COD/BOD ratio is low (4.0), it may not be advisable to use a biological system, and it may be necessary to evaluate the potential for using a chemical treatment system instead [13].

To analyse biodegradability, BOD:N:P is one of the most important indicators in wastewater pollution measurement as well as in drinking water monitoring, comparing the biological demand for oxygen, nitrogen and phosphorus. A minimum BOD:N:P ratio of 100:5:1 is used for aerobic pro- cesses and a COD:N:P ratio of at least 350:7:1 for anaerobic processes [13]. Some authors, such as those mentioned in Table 1, have conducted studies in the sugar industry and have shown some characteristic results. The table shows that, in general, most of the results for industrial effluent treatment are in the range of primary and secondary treatments [11; 12; 13].

Table 1. Effluent parameter values of some authors

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

The Mozambican acucareira (Mafambisse) industry lacks a wastewater treatment system. Waste- water is simply discharged into the environment without prior treatment. In this study, we aimed to analyse the wastewater effluent and identify the most effective treatment method. To do this, we analysed the BOD/C COD ratio to determine the optimal wastewater treatment method. The results of the effluent analysis indicated that the BOD/COD ratio was less than 2. This value is within the range of 1.8 to 2, which is indicative of a low to moderate level of pollution. The biological treat- ment method was found to be the most suitable for this type of pollution. If the values were higher than 2.5, another type of treatment, such as UASB, would have to be used, depending on the type of pollution. The novelty of this research is the following: these values were obtained for the first time in a laboratory environment, which allowed us to identify a suitable treatment system.

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2.- MATERIAL AND METHODS

2.1 Description of sampling sites

The Mozambique Sugar Factory (Mafambisse) is a sugar industry located in the district of Dondo, south of the city of Beira, 1 kilometre from National Road 6 (EN6). The sugar factory has been managed by the company Tongaat Hulett since 1996. Tongaat Hulett is a South African company operating in the sugar industry in several South African countries: Mozambique, Botswana, South Africa, Swaziland, Zimbabwe and Namibia. The sugar industry normally consists of two production sectors: the agricultural sector, i.e. the sugar cane field, and the processing sector (factory) [14-19]. In Mozambique, Tongaat Hulett has factories in Xinavane, Maputo province, and in the adminis- trative post of Mafambisse, Dondo district, Sofala province, with the mission of promoting services and products derived from sugar cane, improving properties, seeking customer satisfaction and the development of the country, taking care of environmental protection [6,7].

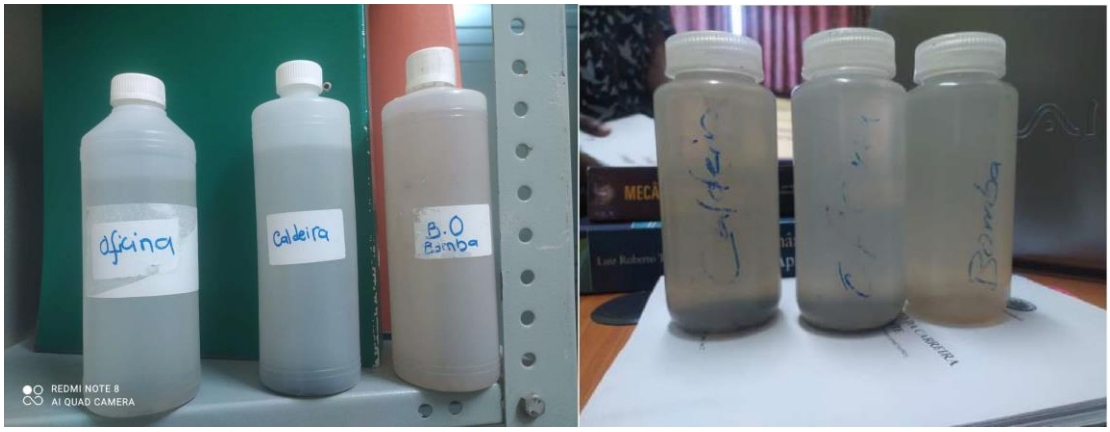
However, they use large volumes of water, ranging from [900m3 to 1000m3]/hour extracted from the Púngue river for cooling machines, bearings, mills, boilers, etc.

2.2 Sample collection and analysis

The sugar cane transformation process is highly complex, generating significant amounts of waste- water composed of liquid and solid discharges from the processing, handling and transformation of sugar cane. These discharges result from the cooling, heating, extraction and reaction processes, as well as from washing 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 crystallisation of the sugar, its pollution load in terms of organic matter and various contaminants increases significantly. Approximately 75% of the total volume of effluent discharged by the sugar cane industries is due to cane washing, which also includes washing water from tanks containing processing residues. On the other hand, the processes of defibration and milling, which extract the juice, give rise to solid waste, namely bagasse, which is composed of fibre [8].

All effluent samples were collected and analysed 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, samples were collected in 500 ml PET bottles using a handmade colle- ctor. After collection, the bottles with the samples were properly identified and transported in an insulated box to the Microbiology and Biochemistry laboratories of the Department of Industrial Process Engineering, University of Zambezi for analysis. The collection process was carried out throughout the 6-month study period, at 2-monthly intervals, in the pump sections (total factory effluent), boiler outlet and total workshop effluent. As shown in fig.1.

Fig. 1. Photo of effluent samples taken in workshops, pumps and boilers.



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To measure the physico-chemical parameters (temperature and pH) at the sites, the instantaneous sampling technique was used in accordance with the standards.

In all cases, the wastewater samples were collected in pre-cleaned and acid-washed plastic bottles and stored in a refrigerator at 4°C until they were used for analysis. Finally, laboratory analyses of the wastewater samples were carried out according to standard methods in our local laboratories.

Among the physico-chemical parameters of the sugar industry wastewater, pH and temperature were measured immediately on site, while the other physico-chemical parameters, such as total solids (TS), suspended solids (TSS), BOD, COD, chloride and sulphate tests, turbidity, alkalinity, density and conductivity, were analysed at the University of Zambezi (Mozambique).

Most sugar producing countries have liquid effluent control standards that limit organics to between 15 and 60 mg/L BOD (Biochemical Oxygen Demand). However, India has a limit of 100 mg/L (Purchase, 1996). Effluent treatment can be carried out in anaerobic or aerobic lagoons [9].

Table 2. Values of physico-chemical parameters of the Mozambique sugar plantation.

Parameters	Pump	Boilers	Offices	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 (mg/L)	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

On the other hand, the South African legislative framework has not changed significantly during the period under review. Existing legislation addresses technical issues, fills some gaps in the legislation, improves some provisions and updates obsolete references.

3.- RESULTS

The physicochemical properties of the wastewater from the sugar industry studied here are well above the limit values of the legislation in force (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 m3 /h), it would be better to use aerobic lagoons, since with a residence time of more than 120 hours or up to 7 days, the reduction of the temperature to ambient values is guaranteed and the occurrence of aerobic pro- cesses is allowed, which could reduce the pollutant load, according to references [12,13].

The results of the COD/BOD ratio for the present study in the different study areas range between

1.48 and 2.0, respectively for the pump, boiler and workshop sectors, the average ratio being 2.0, which indicates that for this range the suggested treatment technology according to [13] is of the secondary biological type.

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.

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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 set 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 bet- ween 1.4 and 2.0, well below the established limits, indicating the high biodegradability of the effluent load.

The suggested technology is therefore biological treatment. To analyse biodegradability the BOD:N:P ratio is used, which is one of the most important indicators for measuring pollution in wastewater. 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.

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