Feasibility of Treating Brewery Wastewater using Bio films

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Abstract

The brewery industry is one of the major industries in Zimbabwe and the following study was conducted to assess the techno-economic feasibility of reuse of wastewater after treatment using the biofilm that forms on the bio carriers. The malting plant of a certain brewing plant uses up to 350000 cubic meters water a year discharging about 75% of the biologically contaminated water as effluent which is discharged into the ecosystem. A biological water treatment approach was done using a moving bed biofilm reactor, with use of Mutag biochips. The treatment resulted in 93% BOD reduction, 87.9% COD reduction, 48% TSS reduction, 44% TDS reduction and a 97.8% increase in DO at a treatment period of 24 hours. An economic analysis was done with a payback period of 2.09 years and return on investment of 49% indicating the techno-economic viability of brewery wastewater.

Keywords: Brewery wastewater; bio film carriers; economic analysis; wastewater reuse

1. Introduction

Zimbabwean industries are characterized by outdated water treatment methods, some that are becoming less effective due to introduction of modern era chemicals and techniques to the industrial processes. There is therefore a call to adopt modern methods of effluent treatment, which are cost effective and efficient in treating water such as the moving bed biofilm reactor (MBBR) which has the potential to treat wastewater with high organic pollutants (Dong et al., 2011; Borka et al., 2013; Burghate and Ingole., 2013). For example the beverage industries incur huge costs in acquiring fresh water from the city council of which the costs can be cut down by means of setting up a water treatment plant that treats the water to the standard of fresh water that it can be used in the plant itself. Water recycling is not only economical but also human and ecologically ethical. The brewery malting plant of a certain brewing plant uses up to 350000 cubic meters of fresh water a year (converting to

140000 US dollars annually) discharging about +75% of the biologically contaminated water as effluent which is discharged into the ecosystem. The current challenges in industries is providing a system that fail to treat effluent (wastewater) to meet the Environmental Management Authority (EMA) standards that the water can be re-used for brewery processes. The use of the MBBR technology is set to address the challenge by means of employing biological means to treat effluent, which have no negative impact to the environment and people providing clean and fresh water for the plant. This study utilizes the biofilm carries to treat the wastewater that it can be re-used in the plant at the same time meet the EMA effluent disposal guidelines (Gullicks et al., 2011; Shiraz, 2011; Ibrahim et al., 2012; Khaled et al., 2014).

2. Experimental

2.1 Selection of the Biofilm Carrier

The biofilm carrier chosen for this process is the Mutag biochip which originated from Germany and is shown in Figure 1. The selected biofilm carrier is a high performance biofilm carrier media with a protected active surface are of 3000 m^2/m^3 and 20g of the bio carriers were added to be added as the biofilm carriers during the experiments.

Figure1. Mutag biofilm carriers used brewery wastewater treatment

2.2 Procedure of Purifying Waste Water Using Biofilm Carriers

The effluent is allowed to settle in the reactor and biofilm carriers are introduced. The polyethylene biofilm carriers provide a large surface area for microorganisms to grow on and perform specific biological treatment functions. Carriers are kept in suspension in the reactor either by the aeration system and the bacteria from wastewater attach themselves to the floating carriers.

2.3 Using the Bio Film Carriers in Brewery Wastewater Treatment

A 1 500 mL container was used as a batch reactor. The wastewater was put in the beaker that contains biofilm carriers and allowed to mix, a pipe was connected into the beaker at the other end is to allow dissolving of oxygen which helps the bacteria on the biofilm carriers to degrade pollutant. After purification, the mixture was filtered by just screening to hold back the biofilm carriers and the purified water was collected in another beaker. The samples were collected at different time intervals to determine the best time span for efficient removal of waste. Comparison of results after treatment against results before treatment and EMA standards were done.

2.4 Wastewater Physicochemical Properties Determination

The brewery wastewater's physicochemical parameters were measured before and after using the biofilm carriers. The wastewater biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), turbidity, pH, electrical conductivity (EC), total dissolved solids (TDS) and the total suspended solids (TSS) were measured in accordance to the standard procedures (Apha, 2005).

3. Results and Discussion

Effective BOD removal of around 93.4% was noticed after 12 hours in the laboratory MBBR set up, this was due to the accumulation of the suspended particles on the biofilm resulting increase in biofilm growth with increase in treatment time (Table 1). The same can be concluded for an 87.9% change in COD between 6 hours to 24 hours of exposure to the biofilm carriers. COD contribute to the level of ions in the water, which has direct effect on electro-conductivity. Some microorganisms contribute to electro-conductivity by means of their bodies. Decrease in the above mentioned parameters resulted in the 70.9% decrease of EC @25 °C. The same trend in BOD and COD reduction was observed by Zafarzadeh *et al*. (2010) for an MBBR system that was focusing on biological nitrogen compounds removal in wastewater.

The increase in the biofilm carriers mass is due to the removal of BOD, COD, removal of TSS (48.4%) and TDS (44.0%) (Table 1). The TSS and TDS levels were not reduced as expected due to the inadequate mixing of the water during the MBBR process by the air pump being used. The DO was noticed to rise by 97.8% as time increased this was so because BOD and COD, which are involved in use of oxygen for oxidation, decreased hence allowing oxygen to dissolve in the water freely without being consumed. The treated effluent met the EMA effluent disposal guidelines from 12 hours of treatment (Table 1).

3.1 Selection of the Optimum Time for Reaction

High removal of pollutants was observed at 24 hours and according to the experimental studies chapter it can be suggested that if the time for purification is prolonged so will the reduction percentage in pollutants but there are many factors that contribute in selection of the optimum period for purification.

Table 1. Brewery effluent results from the MBBR tests

Parameter	Raw brewery effluent	Treated sample @ 6 hrs	Treated sample @ 12 hrs	Treated sample @ 24 hrs	% Reduction	EMA Effluent disposal guidelines
COD (mg/L)	673 .00	284.00	43.80	39.40	93.4	30-50
TSS (mg/L)	2695	2156.0	1886.50	1293.6	48.4	25-50
TDS (mg/L)	1266	1012.80	886.20	557.04	44.0	500-1500
EC @25 °C (µS/cm)	3866.00	2497.00	1125. 00	1082.00	70.9	1000-2000
pH @25°C	8.70	8.20	7.80	7.20	0.1	6.0-9.0
DO (mg/L)	7.23	34.00	78. 00	93.00	97.8*	≥ 60
BOD (mg/L)	607.00	238.00	73.00	57.00	87.9	60-90
Mass (g) before loading bio-chips	980.90	980.90	980.90	980.90	-	-
Mass (g) after loading 183.8g biochips	-	1 164.30	1175.70	1178.1	-	-
Mass (g) after filtering and purification	-	980.77	980.41	980.31	-	-
Mass of biofilm (g) generated	-	0.40	11.49	13.70	-	-

**DO concentration increased upon using the biofilm carriers in brewery wastewater treatment*

4. Process Design

The process design was based on a local brewery company with a 500 m^3/day wastewater generation process.

4.1 Wastewater Characteristics

Key characteristics of wastewater that must be considered in designing include physical, chemical, and biological characteristics of the wastewater and these are obtained from the experimental data.

4.2 Material Balances on Water Treatment Process

The material balances were deduced from experimental data obtained. The data used is for the proposed 24-hour plant. If the overall reduction is 0.05 on a small scale plant emanating a pilot scale, hence the material balances for the larger plant with the required purification of 500 m^3/day will be as indicated in Figure 2.

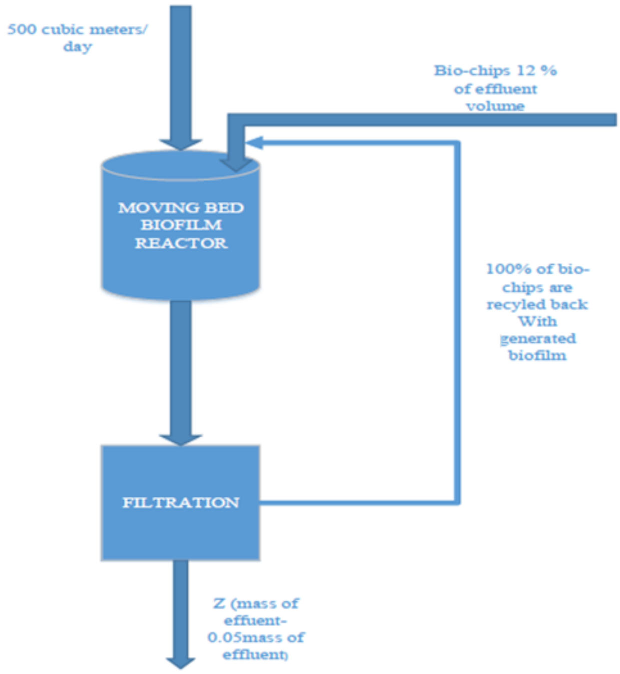

Figure 2. Diagram for mass balances on water treatment process

5. Economic Analysis

This section analyzed profit forecasts, payback period, break-even analysis and return on investment to determining the economic and financial viability of the project (Peters and Timmerhaus, 1993).

5.1 Bill of Quantities and Capital Investment

The bill of quantities included pipes, bio carriers and equipment and was costed to be $192 091. Whist the capital investment was $292 837.

5.2 Sales Revenue

The sales revenue summary is given in Table 2.

Table 2. Revenue from the improved wastewater treatment

Item	Value
Daily production	500 m^3/day
Monthly production	15000 m^3/month
Annual production	180000 m^3/year
Total cost of production	US$ 94000
Production cost per m^3	$0.52

5.3 Calculation of Savings

The information on savings is given in Table 3 assuming 365 working days in a year and 8 working hour s per day.

Table 3. Calculation of savings on improved wastewater treatment

Item	Value
Cost of municipal water to be substituted	$1.30/ m^3
Cost of recycling water	$0.52/ m^3
Cost of municipal water per year	$1.30/ m^3 *180000 m^3/year = $234000
Cost of recycling water per year	$0.52/ m^3*180000 m^3/year = $93999.99
Money saved	$234000-$93999.9 = $140000.01

5.4 Financial Indicators

The payback period which is calculated as the ratio between total capital investment and the profit was (292837.09/ 140000.01) 2. 09 years. The return on investment which is calculated as the ratio between profit and the total capital investment was 49%.

Using on the cost-volume-profit (CVP) formula: px = vx + FC + Profit, p is the savings per unit which is equal to US$0.77 whilst x is the number of units which is 180000 m^3. Whereas v is the variable cost per unit with the value of US$82000/180000 which equals to US$0.45 and FC is the total fixed cost which equals to US$292837. But at breakeven we assume the profit will be zero, so the equation can be written as px = vx + FC. Breakeven point is reached after producing 250288.1 m^3 of clean brewery effluent (Figure 3).

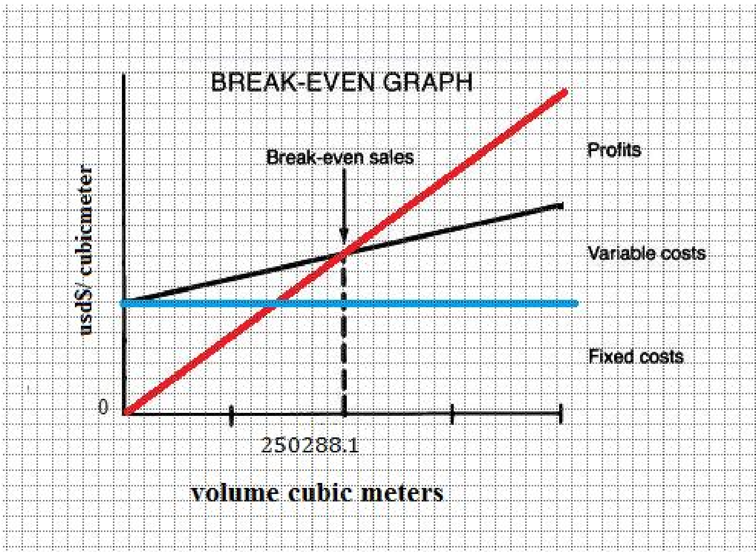

Figure 3. Breakeven analysis chart

6. Conclusion

The biofilm carriers effectively treat brewery wastewater to meet the set standards for effluent disposal. A reduction of at least 44% was achieved for the BOD, TSS, TDS, EC and COD. An economic assessment for application of the technology in the in the brewery industry wastewater at small scale indicated its viability with a payback period of 2 years and internal rate of return of 49%.

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