Performance Evaluation of Cultured Bacteria in the Treatment of Opaque Beer Brewery Wastewater

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Abstract: ***An evaluation of the performance of a mixed culture of bacteria in reducing the organic content of effluent from an opaque beer brewing plant was carried out in this study. In this study brewery wastewater characterization was done and bacterial culture was then added to the wastewater. Biological treatment was done at ambient temperature to reduce the chemical oxygen demand (COD). The maximum treatment efficiency(TE) achieved in terms of COD was 72 % and for Permanganate Value (PV) it was 69 % whilst the Total solids (TSS) reduction was from 1220 mg/L to 400mg/L. The results indicated that the mixed culture was effective for treating opaque beer brewery wastewater at room temperature 25^{0}C to meet the specified quality parameters of the effluent that can be discharged into municipal waterworks. Breweries can therefore apply enhanced biological methods to reduce the organic content of their wastewater.***

Keywords: Cultured bacteria, brewery wastewater, biological treatment, efficiency

1. Introduction

During opaque beer processing large volumes of water are used as well as discharged. The raw materials used include sorghum malt, barley malt, lactic acid, straight run maize meal, and yeast (which initiates fermentation). Water is used for the production of beer, for cleaning tanks and floors as well as for packaging and this therefore means that the resultant wastewater has a low pH as well as large amounts of organic matter which can result in water pollution (Parawira *et al*., 2004: Chaitanyakumar *et.al*., 2011). This reduces the efficiency of municipal water treatment works if the effluent water is not sufficiently treated before being discharged into public waterways and may affect the water quality by increasing organic matter and Chemical Oxygen Demand (COD) according to Parawira *et al*., (2004). Opaque beer is perishable and the beer that gets sour is destroyed at the brewery thereby contributing to the high solid composition of the wastewater. The dissolved carbohydrates, alcohol from beer waste, suspended solids such as spent grain and yeast contribute to the high organic loads of the brewery wastewater (Parawira *et al*., 2004). Chemicals added to the domestic water for cleaning purposes may give rise to wastewater with a high level of inorganic constituents such as calcium, sodium and sulphate (Uwidia & Ademoroti, 2012). Pathogens which transmit communicable diseases are also present in wastewater and they cause water borne diseases such as diarrhoea, cholera, typhoid and hepatitis (Uwidia & Ademoroti, 2012). Wastewater from industrial and agricultural activities is treated and reused due to the scarcity of water and there is therefore need to effectively treat the effluent water from industries before discharging it into municipal sewage systems. Chemical and biological composition must be closely monitored to avoid disease outbreaks. Currently the municipal water works are not fully functional in Harare and so manufacturing industries should closely monitor their effluent before discharging it into municipal water systems to reduce the unwanted matter in water. Again there are severe restrictions by Harare municipal authority (Parawira *et al*., 2004: Manhokwe *et al*., 2009). This has been a greater challenge for the food processing industry, particularly the brewing industry since it produces wastewater with a high organic matter content as well as high acid content.

Water being treated at a local brewery is falling out of City council specifications by huge margins of discrepancies. The treatment efficiency of the current system is failing to achieve the specified limits and the brewery is constantly fined for polluting by local Environmental Management Agency (EMA) and Harare City Council. Several methods have been adopted by the brewing industry in order to reduce the organic matter in their wastewaters but still pollution by industries is very high. To be able to meet these specifications, industries must come up with effective on-site treatment methods so as to reduce the pollution fines imposed by local authorities on polluters.

Biozyme is a ready to use bacterial powder formulamade of wheat bran grain- like substance as a substrate, and used for accelerating organic wastes degradation in commercial wastewater facilities, polluted underground water sources, and sewage pits. This bacterial powder has the ability to accelerate the breakdown of difficult to degrade organic compounds in aerobic and anaerobic environments at a pH range of 7.8-8.2. Bacterial strains in the biozyme blend produce enzymes which help them to break down large molecules into smaller pieces that can be easily transported into the cell to be metabolized for energy. The use of commercial cultures is that they achieve the intended objectives in a shorter period as compared to conventional methods of biological treatment. Biozyme has been used in improving the efficacy of treatment systems and odor control in a variety of industries including dairy processing, meat processing, bakeries and all facilities which generate organic contaminated wastewater.This research seeks to assess the effectiveness of applying biozyme to improve the current treatment method being used at a local brewery.

2. Methodology

Brewery Sample Collection

Samples were collected from the equalization tank and transported in cubed ice so as to avoid the changes that are caused by microbiological activity which may change the oxidation state of some constituents as cited by Polit and Hungler (1997). They were also kept under refrigeration at 4^0C in the laboratory prior to analysis to prevent the above mentioned changes. Laboratory analysis was started within a period of 24 hours so as to keep the time between sample collection as short as possible which helps to prevent biodegradation and volatilization of the sample. New plastic containers were used so as to avoid using containers with organic contaminants. The samples were mixed thoroughly to permit removal of representative aliquot. Laboratory grade distilled water was used to minimize contamination of the samples.

Characterisation of Wastewater

Untreated opaque beer brewery wastewater was analysed for PV, TSS, pH and COD using the standard methods described by American Public Health Association (1999). Analyses were done to assess the overall quality of the wastewater before treatment. The COD, PV, TSS and pH were analysed in duplicate.Samples were analysed using HANNA COD test kit Medium Range EPA Dichromate (HI 93754B-25) which is based on the Standard Open Reflux Method.

The permanganate value (PV) is a method of determining the organic matter in wastewater. The PV is a measure of oxygen absorbed from acidified potassium permanganate during 4 hours at 27 °C. In this method, 50 ml of 0.0125 N potassium permanganate was poured into 250 ml conical flask, followed by 10 ml (25 % H_2SO_4). A sample (10 ml) was diluted to 100 ml in a measuring cylinder using distilled water and poured into the conical flask. A blank was run concurrently using 100 ml of distilled water in place of sample. The flasks were tightly stoppered and stored in a dark cupboard at 27 °C for 4 hours. After 4 hours of incubation 5 ml of potassium iodide was added and the solution titrated against 0.025 N sodium thiosulphate. Starch indicator (1 % w/v) was used to detect the end-point, which was the disappearance of the blue-black starch-iodine color.

Wastewater Treatment

Biozyme was obtained from a local supplier and stored away from direct sunlight and in a tightly closed container as specified by the supplier. Biozyme was added to wastewater samples at 25ppm, 40ppm and 80ppm to degrade the organic matter. This was done at 25^0Cwith gentle agitation using REMI RS-12R rotary shaker at 60rpm to ensure homogeneity. Adjustment of pH was done using standard grade soda ash. The samples were put into 1liter flasks and the flasks were gently agitated using to ensure REMI RS-12R rotary shaker at 60rpm for homogeneous distribution of the sample, biozyme (25 ppm, 40 ppm, 80 ppm) and soda ash at room temperature. The samples were allowed to stand for up to 48 hours to give the biozyme enough time to digest the organic matter.

3. Results and Discussion

Table 1: Characteristics of brewery wastewater

Parameter	Brewery wastewater	Permitted value EMA Act, S I of 2007
COD (mg/l)	4709 ± 4	60
PV (mg/l)	152 ± 5.57	60
TSS (mg/l)	1220 ± 0,03	50
pH	7.64 ± 0,18	6.8 -9

From Table 1 above, it is evident that the brewery is discharging effluent that does not meet specifications of the environmental regulations. The COD is above the permitted maximum for the red category of 500mg/l. However, the pH is within permissible limits.

Change in COD after treatment with Bio-zyme

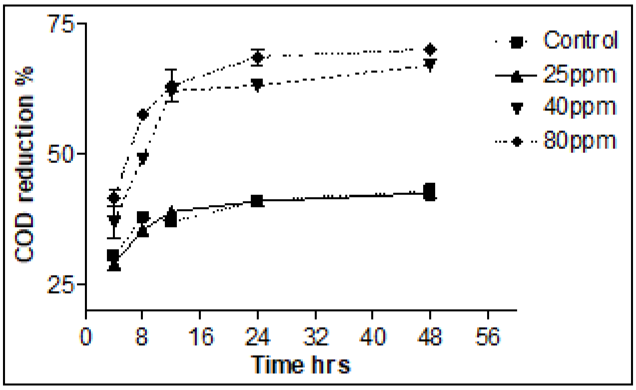

Figure 1: Effect of biozyme concentration on COD reduction

Figure 1 illustrates the effect of biozyme concentration on reducing the chemical oxygen demand of the wastewater. Maximum TE (treatment efficiency) achieved in terms of COD after 48 hours was 72%. The result indicates that biozyme was effective in reducing the COD in brewery wastewater at ambient temperature ($21\text{-}30^0$C). The wastewater COD was reduced from 4709 mg/l to values as low as 1318 mg/l. It is also clear that biozyme was more effective at a higher concentration of 80ppm as compared to 25ppm as illustrated in figure1 above. There was a significant difference ($p< 0.05$) in COD reduction between biozyme treated brewery wastewater and brewery wastewater that was not treated with biozyme.

The COD removal efficiency attained in this study is comparable to an average of 57% obtained in a study of industrial anaerobic treatment of opaque beer brewery wastewater using a full-scale UASB reactor seeded with activated sludge by Parawira *et al* (2004). Kilani (1993) in a study, using comparative laboratory-scale study of the effects of dairy and clear brewery effluents on the treatability of domestic sewage achieved an average COD removal of 60%. Stadlbauer *et al* (1994) in another study of anaerobic purification of lager beer brewery wastewater using laboratory scale biofilm reactors with and without a methanation cascade reported COD removal efficiencies of 85-90%. Manhokwe *et al* (2009) suggest that the reduction in COD is due to the good amenability of starch, protein and other organic molecules present in the sample. COD reduction is also as a result of the removal of solids from the

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wastewater (Chaitanyakumar *et al*, 2011; Uwidia and Ademoroti, 2012). The performance of biozyme in the current study can however be improved to attain even higher COD removal efficiencies in brewery wastewater.

Change in Permanganate Value after Treatment with Bio-Zyme

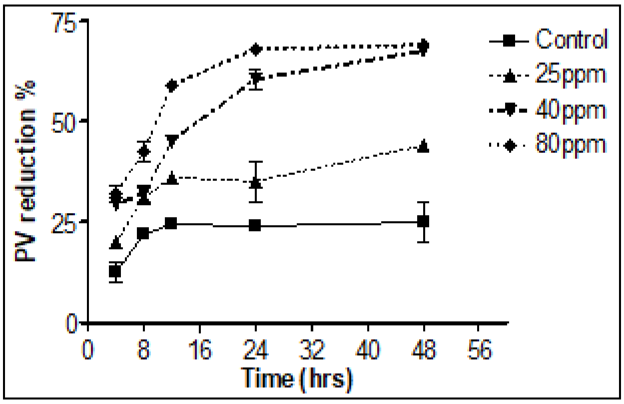

Figure 2: Effect of biozyme concentration on PV reduction

Figure 2 shows the effect of biozyme concentration on PV reduction. The maximum average TE achieved in PV reduction was 69 %. A maximum PV reduction of 69 % was achieved in the sample with higher biozyme concentration (80ppm) whilst at 25ppm the maximum reduction achieved was 45 %. There was a significant difference ($p<0.05$) in PV reduction between the brewery wastewater treatments with biozyme. The attained PV removal efficiency is comparable to that achieved in other researches done before. Parawira *et al* (2004) reported an average PV removal efficiency of 62%.

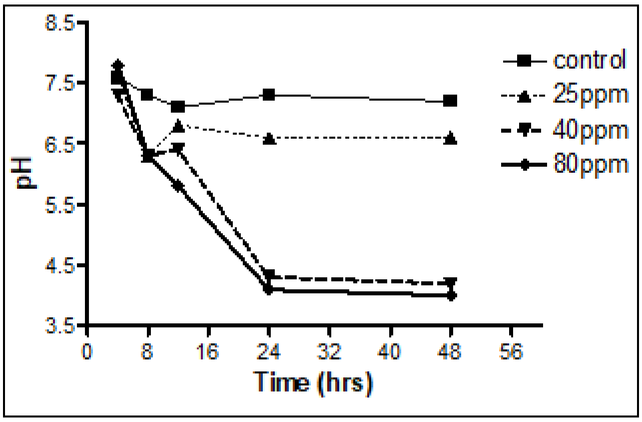

Figure 3: Effect of biozyme concentration on wastewater pH

Figure 3 illustrates the change in pH of the wastewater after it was treated with biozyme. It is evident that after the addition of biozyme there was a reduction in the brewery wastewater pH from 7.6 to 4.2 within a period of 48 hours at 25ppm whilst at 80ppm the reduction was from 7.8 to 4.0. This drastic change shows that biozyme had the effect of lowering wastewater pH.

The fall in pH can be the result of the oxidation of organic matter present in the wastewater by the enzymes present in biozyme to organic acids such as butyric acid, propionic acid and other short chain fatty acids as well as alcohol (Shchurskaya & Trotsenko, 2014). Wastewater with a low pH is not suitable for discharge into the municipal waterways as it disturbs aquatic life (Golub *et al.*, 2001). The current study could not successfully increase the pH but it cannot be concluded that biozyme is not effective in controlling wastewater pH.

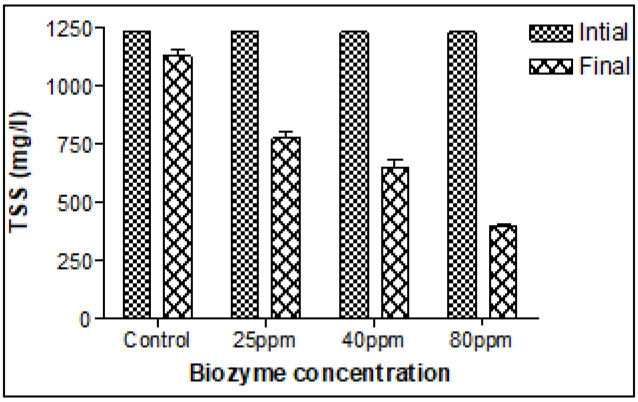

Figure 4: Effect of biozyme concentration on TSS reduction

Biozyme was added to opaque beer brewery wastewater at 25ppm,40ppm and 80ppm to determine the effect of biozyme concentration in reducing the total solids. Figure 4 shows the reduction from 1220 mg/l to an average of 400 mg/l at 80ppm biozyme concentration whilst at a concentration of 25ppm biozyme the maximum average reduction was from 1220ppm to 800ppm). From figure 4 above, biozyme had the capacity to reduce total solids in beer brewery wastewater to the maximum tolerable levels by the Harare City council. There was a significant difference ($p<0.05$) in TSS reduction between biozyme treated brewery wastewater and brewery wastewater not treated with biozyme. The reduction in solids may be due to the utilization of the solids by enzymes and bacteria in biozyme.

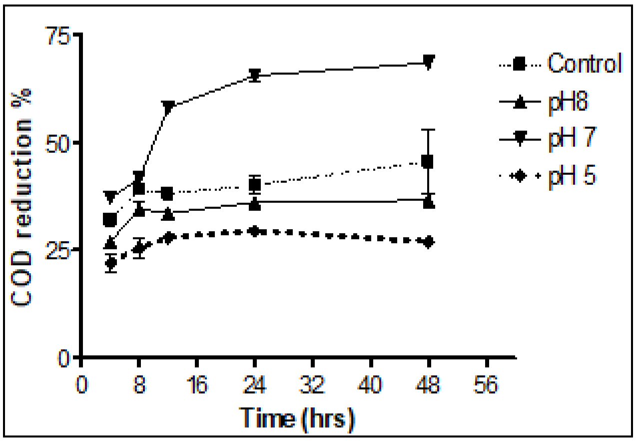

Figure 5: Effect of pH conditioning on PV reduction at 80ppm biozyme concentration

Figure 5 shows the activity of biozyme in reducing PV after the pH of the opaque beer brewery wastewater was conditioned soda ash at a constant biozyme concentration of 80ppm. An average maximum PV reduction of 69 % was achieved at pH 7. At low pH an average TE of 28 % was attained whilst that conditioned to pH 8 achieved a maximum PV reduction of 38 %. Raising the pH using soda ash reduces the capacity of biozyme to reduce wastewater PV as compared to the samples without pH conditioning.

There was a significant difference ($p < 0.05$) in PV reduction between brewery wastewater that had been pH conditioned and brewery wastewater that had no pH conditioning.

There was a continuous fall in pH with increasing time. The explanation to this effect could be that the action of acetogens also contributed to low pH values due to acetic and propionic acid synthesis as well as other short chain fatty acids (Laubscher *et al.*, 2001). Several studies have found out that carbon dioxide production and ammonia oxidation also contribute to a decreased pH of wastewaters and this could have contributed to the low pH values obtained in the current study. Another study suggested that pH change in wastewater is influenced by the buffer capacity (resistance against pH change in acids or alkali) and the production of acid or alkali during the biological treatment process. The buffer capacity is affected by the wastewater alkalinity whilst the production of acid or alkali depends on wastewater quality and process parameters such as reaction time, aeration and temperature. Lactic and acetic acids are transitional products formed during the metabolism of carbohydrates and these are present in opaque beer brewery wastewater. These are said to be fully oxidized under aerobic conditions but since the experiment was carried out under anaerobic conditions it can be concluded that they were not fully oxidized and contributed to a low pH in the wastewater.

4. Conclusion

Biozyme was found to be effective in reducing the organic load in brewery wastewater as shown by the decrease in COD, PV and TS. It is evident that the wastewater being discharged from the brewery does not meet the local specifications of effluent quality. The findings of the research indicate that biozyme can be safely applied to wastewater as a way of improving current wastewater treatment methods at the local brewery and other wastewater producing industries. The reduction in wastewater will largely benefit the environment since pollution levels will be less in water bodies.

Conflict of Interest

Author declares no conflict of interest

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