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*Full Length Research Paper*

# Treatment of a mahewu processing plant wastewater using coagulant Ferrifloc 1820

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**Wastewater from a mahewu processing plant was collected for characterisation and jar testing using Ferrifloc 1820 and a combination of Ferrifloc 1820 and the polyelectrolyte Magnafloc. Treatment showed that Ferrifloc 1820 caused a statistically significant decrease on both the chemical oxygen demand (COD) and oil and grease content of the wastewater. The mean decrease for the COD using Ferrifloc 1820 was 65.24% with the mean oil and grease reduction using Ferrifloc 1820 being 94.58 %. The polyelectrolyte Magnafloc was shown to have a statistically significant impact when used in combination with Ferrifloc 1820 on the COD. However, it did not show any statistically significant impact in the reduction of the oil and grease content of the wastewater. Although the treatment of the wastewater using Ferrifloc 1820 yielded significant results in the reduction of COD and oil and grease, the resultant results did not meet the Zimbabwean legislative standard for discharge. The resultant decrease of the oil and grease of the mahewu effluent due to this treatment makes it desirable to apply the use of Ferrifloc 1820 as a pre-treatment method for anaerobic digesters. There is need however, to determine the optimal pH and temperature and other operational parameters for Ferrifloc 1820 in the treatment of the mahewu wastewaters.**

**Key words:** Mahewu, chemical oxygen demand, coagulant, polyelectrolyte.

## INTRODUCTION

The application of biotechnology in the food processing and preservation industry extensively has resulted in the commercialisation of traditional methods for making fermented foods and beverages such as bread, beers and wines, and fermented milk products. Mahewu is one of the traditional foods that has seen research being applied leading up to the commercialisation of its production (Gadaga et al.,1999; Parawira and Khosa, 2009).

Mahewu is a cereal based non-alcoholic beverage that traditionally has a national nutritional significance in Zimbabwe as it is used for the weaning of children. It is prepared from either thin or thick maize porridge. The porridge is mashed and mixed with sorghum or millet or wheat and left to ferment at ambient temperatures. Industrially, flavour reagents, stabilisers and milk are added to the formulations (Gadaga et al., 1999).

Dairy fortified mahewu and dairy fruit mix beverages

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processing are emerging as big businesses in Zimbabwe as evidenced by the entry into this industry by the major beverage companies such as Delta Beverages, Dairibord, Igwebu and Rainbow Beverages whom have invested in dairy fortified mahewu processing plants. It was reported that, amid a decline in its sales volumes and cash inflow, Delta Beverages reported a growth of 11% in its mahewu and dairy fruit mix beverages division and has commissioned additional capacity at its plant in addition to rolling out new flavours (Kadzere, 2015).

Despite this growth, there are no published scientific reports on the treatment of dairy fortified mahewu wastewater. Treatment of food and beverage wastewater prior to discharge into the environment is desirable so as to avoid environmental pollution (Vanerkar et al., 2013). Physico-chemical processes such as coagulation and flocculation can be applied in the area of wastewater treatment either as pre-treatment or polishing treatment or as specific treatment for reuse as process water (Vanerkar et al., 2013).

These processes are often applied for the removal of heavy metals, oils and greases, suspended matter, emulating organic substances, organic and inorganic compounds, non-polar organic substances, toxic pollutants and phosphorus (Vanerkar et al., 2013; Johnson, et al., 2008). Ayguna and Yilmazb (2010), found that coagulation-flocculation processes using ferric chloride can yield 84% chemical oxygen demand (COD) removal when used to treat detergent wastewater. They also found that the addition of polyelectrolytes as coagulation aids improved this removal of COD by 10% (Ayguna and Yilmazb, 2010), a phenomena also reported by Vanerkar et al. (2013).

The aim of this study was to investigate the impact of treating wastewater from a plant that produces dairy fortified mahewu by a commercially available coagulant Ferrifloc 1820. Further to this, the study also aimed to assess the impact of coagulant aid Magnafloc on the efficacy of Ferrifloc 1820 in the treatment of this wastewater.

## METHODOLOGY

Grab samples were collected from a Mahewu processing plant in the Willowvale industrial area of Harare, Zimbabwe on three sampling occasions. The wastewater was collected manually, directly into 25 l opaque polypropylene sampling containers at the point of convergence of all wastewater streams from the processing plant. The bottles were appropriately labelled and stored at 4°C during the trials.

### Stock solutions preparation

A stock solution of Ferrifloc 1820 was prepared by adding 10 ml of Ferrifloc 1820 to 1000 ml distilled water and vigorously shacking the mixture. Another stock solution of Magnafloc was prepared by adding 1 g of Magnafloc into 10 ml of warm distilled water and adding another 990 ml of dissolved water into the solution.

### Treatment with ferrifloc 1820 and magnafloc

Jar tests were done using the Lovibond ET750 model with six stirring places and an illuminated back panel. Aliquots of the wastewater were placed into the 1000 ml flasks of the jar testing equipment. The first jar was used as control and 0 ml of Ferrifloc 1820 was added to it while the other two jars had 1 ml of the Ferrifloc 1820 added to them. The remainder of the jars had 1 ml of the Magnafloc stock solution added to them. The jars were then placed onto the equipment with the stirring paddles fully immersed into the jars. Rapid mixing at 100 rpm was allowed for one minute followed by slow mixing at 40 rpm for 30 minutes. When mixing was completed the mixing paddles were removed and the solutions were allowed to settle. The water from the five jars was filtered using a 24 cm MN 614 Whatman No. 1 filter paper. The treated samples were tested for COD and oil and grease and compared to the raw effluent.

### Chemical oxygen demand

The closed reflux titrimetric and colorimetric method using a COD digester was used to determine the COD levels of the raw effluent samples, Ferrifloc 1820 treated wastewater sample and Ferrifloc 1820 and Magnafloc treated wastewater samples. Test tubes (20 ml) were prewashed with $H_2SO_4$. A 0.50 ml sample was added to a test tube followed by 2.5 ml standard $K_2Cr_2O_7$ and mixed slowly and 3.5 ml of $H_2SO_4$ was added and allowed to go to the bottom of the test-tube. The test tube was capped, mixed and cooled. The test tubes were then transferred to a COD digester (Spectra 2015MCOD) and digested at 150°C for 2 h. Blanks were run by substituting distilled water for the wastewater sample, and the same procedures were followed with 3 blanks being run per sample. The products of the COD digestion were transferred into a 100 ml beaker. Distilled water was added to make the volume 50 ml and 1 to 2 drops of ferroin indicator were added to the samples. The solutions were titrated against 0.05 ml Ferrous Ammonium Sulphate solution using the zaaCT15 COD titrator with the results being displayed directly in ppm.

### Oil and grease

Oil and grease determination was modified from the APHA (1998) method which was described by Westehuizen (2014) as follows:

Wastewater samples (100 ml), Ferrifloc 1820 coagulated and Ferrifloc 1820 and Magnafloc coagulated samples were acidified to pH 2 with HCl (1:1) solution.

For each sample 50 ml was weighed and transferred into a separator funnel and 100 ml ethanol, 20 ml n-hexane and 20 ml diethyl ether were added to the separator funnel and shaken vigorously. The solution was left to settle and separate the bottom layer was drained and the top layer was collected. The collected layer was treated with 20 ml n-hexane and 20 ml diethyl ether three more times. The sample was distilled in a rotavap (Eyela N-1200A series) at 60°C and the distilled sample was measured gravimetrically and quantified (Westehuizen, 2014).

### Statistical analysis

Statistical analysis was performed using IBM SPSS Version 22 software. Comparative analysis involved the use of the paired t-test at 95% confidence interval and the eta squared statistic.

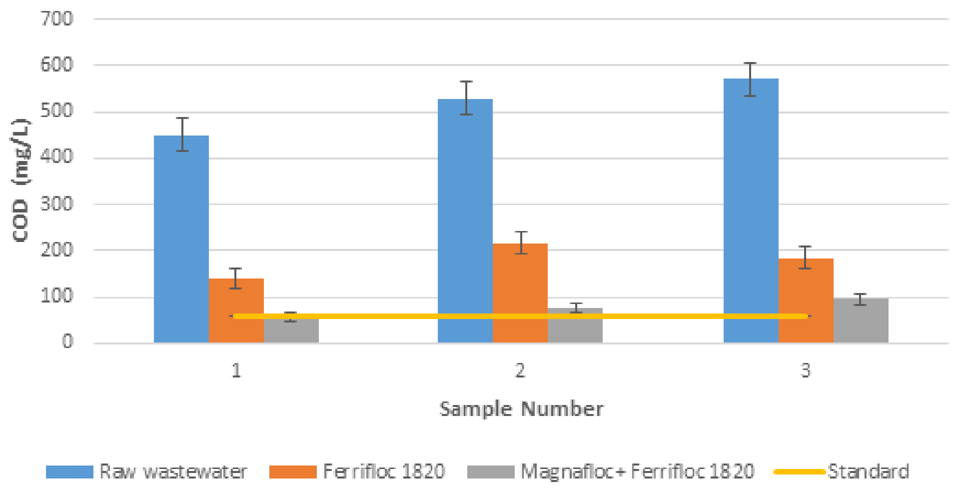


**Figure 1.** COD results for the mahewu processing plant wastewater.

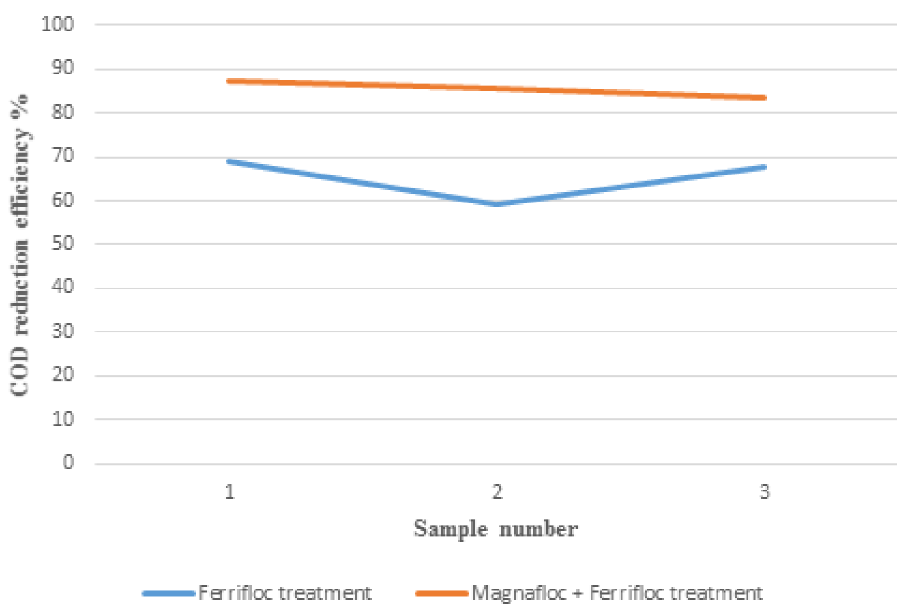


**Figure 2.** COD reduction efficiencies of Ferrifloc 1820 and Ferrifloc 1820+ Magnafloc on Mahewu processing plant wastewater.

## RESULTS

### Chemical oxygen demand

Chemical oxygen demand (COD) is the amount of a specified oxidant that reacts with the sample under controlled conditions (APHA, 1998). The COD the mahewu processing plant waste water ranged from 450 to 570 mg/l. These values were above the amount specified by the Zimbabwean Statutory Instrument 274 of 2000 (S. I. 274 of 2000) which instructs the permissible disposal limit into water bodies of COD to be 60 mg/l (ZINWA, 2000) (Figure 1). The combination of polyelectrolyte Magnafloc and Ferrifloc 1820 on the mahewu processing plant yielded a reduction rate in COD that ranged from 83.3 to 87% (Figure 2).

### Oil and grease

The oil and grease content of the mahewu processing plant wastewater ranged from 703 to 830 mg/l. The amount of oil and grease permitted by S. I. 274 of 2000 is 450 mg/l (ZINWA, 2000) (Figures 3 and 4). The

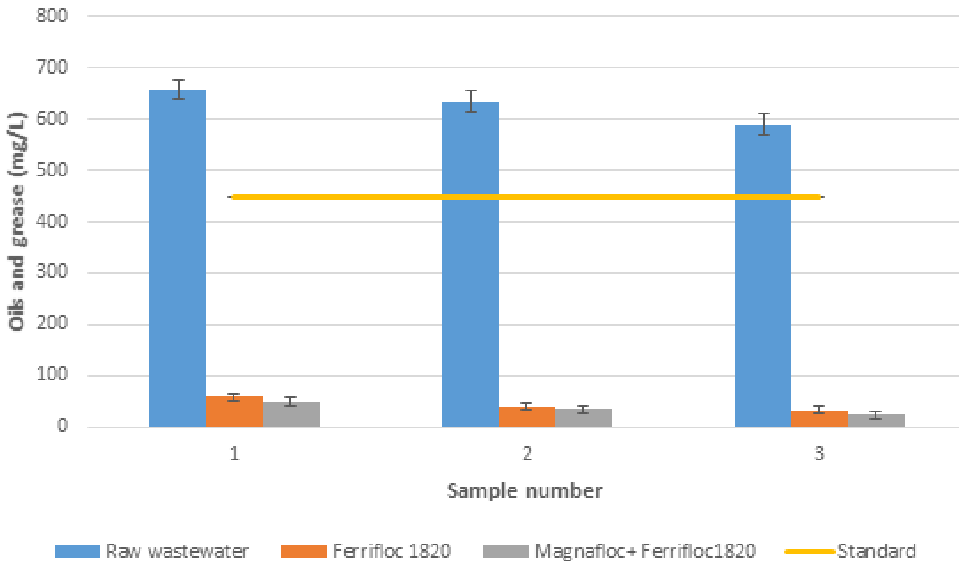


**Figure 3.** Oil and grease results for the mahewu processing plant.

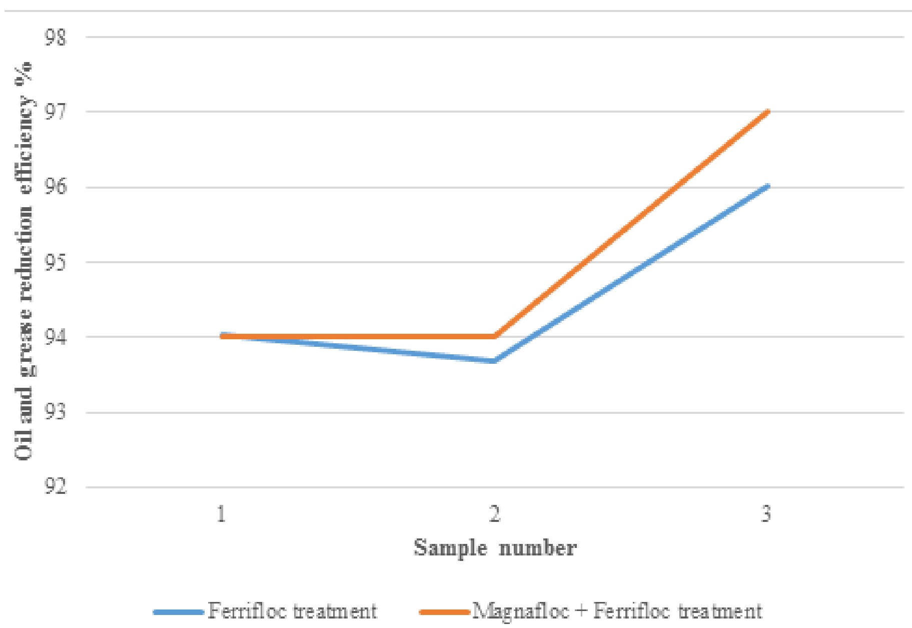


**Figure 4.** Oil and grease reduction efficiencies of Ferrifloc 1820 and Ferrifloc 1820+ Magnafloc on mahewu processing plant wastewater.

combination of polyelectrolyte Magnafloc and Ferrifloc 1820 on the Mahewu processing plant yielded a reduction rate in oil and grease that ranged from 94 to 97%.

## DISCUSSION

The COD values for the mahewu treatment plant wastewater were 450, 530 and 570 mg/l respectively before treatment and these were reduced to 139, 217 and 185 mg/l respectively giving removal rates of 69.11, 59.06 and 67.54%, respectively (Figure 2).

The dosage rates of the Ferrifloc were 10 mg/l for all the samples, 90 mg/l less than the permitted limit according to the products toxicological effects specification. A paired t-test was conducted to evaluate the effect of Ferrifloc 1820 on the mahewu processing plant wastewater COD levels. There was a statistically significant decrease in the COD levels from the raw effluent (M = 516.667 mg/l; SD = ±61.101 mg/l) to the treated effluent COD levels (M = 180 mg/l; SD = ± 39.208 mg/l), t (2) = 13.818, $p < 0.005$ (two tailed). The mean decrease of the COD scores was 336.33 mg/l with a 95% confidence interval ranging from 231.605 mg/l to 441.060 mg/l. The eta squared statistic (0.98) indicated a large effect size.

Ferrifloc 1820 is a combination of ferric chloride and a polyquaternary amine, this makes it a high weight molecular polymer (Westehuizen, 2014). However, the treatment of this effluent by Ferrifloc 1820 did not result in the reduction of the COD to the point 60 mg/l prescribed by S. I. 274 of 2000 for discharge, this treatment has to be followed by another treatment that will further reduce the COD levels to the ones prescribed by the law (ZINWA, 2000).

The oil and grease removal rates using Ferrifloc 1820 were 94.03, 93.68 and 96.02% for the mahewu processing plant wastewater (Figure 4). A paired t-test was conducted to evaluate the effect of Ferrifloc 1820 on the mahewu processing plant wastewater oil and grease levels. There was a statistically significant decrease in the oil and grease levels from the raw effluent (M = 762.33 mg/l; SD = ± 63.91 mg/l) to the treated effluent oil and grease levels (M = 40.89 mg/l; SD = ± 7.37 mg/l), t (2) = 18.05, $p < 0.003$ (two tailed). The mean decrease of the oil and grease scores was 721.44 mg/l with a 95% confidence interval ranging from 549.46 mg/l to 893.42 mg/l. The eta squared statistic (0.99) indicated a large effect size.

These results are in line with Westehuizen's (2014) findings when he treated grain distillery wastewater with Ferrifloc 1820 and got removal rates that ranged from 92 to 95% with an average of 93.80%. In another study, the combined use of magnetic powder and a coagulant yielded FOG removal of 94.2% (Bavar, 2011). The oil and grease levels were reduced by treatment with Ferrifloc 1820 to levels below 450 mg/l allowed for discharge by S. I. 274 of 2000.

**Treatment with combined Ferrifloc 1820 and Magnafloc**

The combined use of Ferrifloc 1820 and Magnafloc on mahewu processing plant wastewater (Figure 2) achieved COD reduction levels of 87.33, 85.7 and 83.33% on the raw waste water. A paired t-test was conducted to evaluate the effect of Ferrifloc 1820 and Magnafloc on the mahewu processing plant wastewater COD levels in comparison with the effect of Ferrifloc 1820. There was a statistically significant decrease in the COD levels from the Ferrifloc treated wastewater levels (M = 180.33 mg/l; SD = ± 39.21 mg/l) to the Ferrifloc and Magnafloc treated effluent COD levels (M = 75.93 mg/l; SD = ± 19.00 mg/l), t (2) = 5.63, $p < 0.03$ (two tailed). The mean decrease of the COD scores was 104.40 mg/l with a 95 % confidence interval ranging from 24.60 mg/l to 184.21 mg/l. The eta squared statistic (0.98) indicated a large effect size.

The addition of Magnafloc to the coagulant lime for the treatment food industry wastewater yielded an increase of 6.4% (Vanerkar et al., 2013). This shows that the pairing of a polyelectrolyte with a coagulant is more effective than the use of a coagulant alone in the reduction of COD. Though there was a reduction in the COD levels of the wastewater, the resultant COD values did not meet the specified COD of 60 mg/l prescribed by S. I. 274 of 2000. Hence, the treatment of this wastewater with Ferrifloc can only be applied as a pre-treatment to subsequent treatment process.

The oil and grease contents of the mahewu processing plant wastewater (Figure 4) was reduced by 94.02, 94.00 and 97.01%. A paired t-test was conducted to evaluate the effect of Ferrifloc 1820 and Magnafloc on the mahewu processing plant wastewater oil and grease levels in comparison with the treatment of Ferrifloc 1820. There was a statistically no significant ($p < 0.05$) decrease in the oil and grease levels from the Ferrifloc 1820 treated effluent (M= 40.89 mg/l; SD = ±7.37 mg/l) to the Ferrifloc 1820 and Magnafloc treated effluent oil and grease levels (M= 37.36 mg/l; SD = ±10.99 mg/l), t (2) = 1.44, $p < 0.286$ (two tailed). The mean decrease of the oil and grease scores was 3.53 mg/l with a 95% confidence interval ranging from -6.99 to 14.06. The eta squared statistic (0.51) indicated a large effect size.

As shown, the combined use of Ferrifloc and Magnafloc has no impact on oil and grease reduction in the mahewu processing plant wastewaters. However, the high oil and grease reduction levels achieved by the Ferrifloc 1820 treatment, it is advantageous to have it applied as a pre-treatment to anaerobic digesters. The reduced oil and grease contents will help in hampering the various operational problems that are as a result of the accumulation of lipids and other colloidal constituencies onto the microbial aggregates by mechanisms of adsorption, precipitation and entrapment (Westehuizen, 2014). These operational problems include but are not limited to biomass washout, clogging, short-circuiting, process inhibitions, poor final effluent and biogas quality at lower HRT and higher OLR (Harush et al., 2011; Rajagopal et al., 2013; Vanerkar et al., 2013).

Polyelectrolytes like Magnafloc are employed for the reduction of the cost and amount of chemical coagulant requirement (Vanerkar et al., 2013; Ayguna and Yilmaz, 2010). The results agree with what Ayguna and Yilmaz (2010) claimed that generally, a little amount of polyelectrolyte dosage is enough to reach high efficiency in the efficacy of a coagulant. They also suggest that when polyelectrolytes are used as coagulation aids the metal coagulant dosage can be reduced without cutting down the performance.

## Conclusions

Ferrifloc 1820 is shown to cause a statistically significant decrease on both the COD and oil and grease content of the mahewu processing plants wastewaters with all assessments showing a large effect size. The polyelectrolyte Magnafloc has a statistically significant impact when used in combination with Ferrifloc 1820 on the COD only. The addition of Magnafloc to Ferrifloc does not show any statistically significant impact in the reduction of the oil and grease content of the mahewu processing wastewater.

## Conflict of interests

The authors have not declared any conflict of interests.

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