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Effect of acti-zyme loading, Retention time and their interactionon sewage physicochemical propertiesduring anaerobic treatment

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ABSTRACT

Acti-zyme, an enzyme biocatalyst was used for anaerobic sewage treatment as a biological means. The sewage total Kjeldahl nitrogen (TKN), biochemical; oxygen demand (BOD), total suspended solids (TSS), total dissolved solids (TDS), electrical conductivity (EC), pH, chloride ions concentration (CI^-), total phosphates (TP), sulphate ions concentration (SO_4^{2-}), dissolved oxygen (DO) and the chemical oxygen demand (COD) were measured. All other parameters were measured by titrimetricmethods; the pH and EC were measured by electrodes whereas the SO_4^{2-} ions were measured by the gravimetric method. Effects of the acti-zyme loading, retention timeand their interaction on sewage physicochemical properties were determined using 2^2 factorial designs. All samples were incubated at 37°C under anaerobic conditions at agitation rate of 60 rpm. Acti-zyme was varied between 35-50 g/m^3 whilst the residence time was varied between 7-40 days. The TKN, BOD, TSS, EC, CI^-, TP, SO_4^{2-} and COD decreased linearly by more than 18% on increased acti-zyme loading and residence time as well as their interactions. The sewage pH changed from being alkaline to neutral and the DO increased by >200%. Optimum sewage treatment conditions to meet set guideline for disposal were obtained at 50g/m^3 acti-zyme loading and retention time of 40 days.

KEYWORDS

Acti-zyme;
Biological sewage treatment;
Physicochemical properties;
Retention time.

INTRODUCTION

Poorly treated sewage, a form of wastewater is being disposed off in water bodies in developing countries due to poor treatment techniques, lack of treatment chemicals or old equipment (Manyuchi and Phiri, 2013; Muserere*et al*., 2013). This poses an environmental threat to the water bodies hence need to utilize environmentally friendly treatment techniques. Acti-zyme, an enzyme biocatalyst which possesses biochemical properties that allows it to be used for sewage treatment can be considered as an alternative sewage treatment method (Tshuma, 2010). Acti-zyme contains enzymes such as catalase, protease and amylase which promote de-toxification of biological contaminants in sewage and has a potential to treat wastewater aerobically or anaerobically. Furthermore, anaerobic treatment of sewage is an attractive option as it can also favors biogas production and releases small quantities of sludge

(Reali*et al*., 2001). Acti-zyme was then applied for sewage treatment and the sewage physicochemical parameters determined so as to ascertain its feasibility in sewage treatment as a biological method.

EXPERIMENTAL

Materials

Raw sewage was collected from the Chitungwiza Sewage Treatment plant in the MashonalandEast area. The sewage plant is monitored by the Harare City Council. Acti-zyme was obtained from AusTech Australia. An Inco ThermLabotec Incubator was used as the anaerobic digester for the 250 mL flasks loaded with sewage. The flasks were covered with aluminumfoilpaper to promote anaerobic conditions.

Methods

The raw sewage was stored at subzero to avoid any microbial activity in the sewage. The raw sewage was tested for pH, total phosphates (TP), total Kjeldahlnitrogen (TKN), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), electrical conductivity (EC), chloride ion concentration (Cl^-), sulphates concentration (SO_4^{2-}) and the dissolved oxygen (DO)(Popa*et al*., 2012; Sarkinnoma*et al*., 2013; Singh and Singh, 2014). The sewage was then treated with acti-zyme loading of 35-50g/m^3 between 7-40 days. All parameters were measured in milligrams per liter (mg/L) except for pH and the EC which was measured in microSiemens per centimeter (µS/cm). Temperature was fixed at 37æ%C and agitation rate in the 250 mL flasks was maintained at 60 rpm. The TKN,TP, BOD, DO, COD, SO_4^{2-} and Cl^- ions concentration were measured using titration methods, TSS and TDS where measured by filtration using the Alpha Standards Methods of determination in wastewater (Alpha, 2005). The EC and pH were measured by the Hanna HI electrode probe. Lastly, the *E. Coli* content was measured through total plate count and the total coliforms by the spread count method.

STATISTICA 12.0 was used to check statistically if there was any interaction between acti-zyme loading and the retention time on the various physicochemical properties at 95% confidence interval. 2^2 full factorial designs were done for each parameter and a center point was also investigated to note the change in the trend as represented in TABLE 1. Experiments were replicated twice. Acti-zyme loading rate was denoted as A and the residence time in the flasks was denoted as B. The (-1) and the (1) indicated the low and the high levels of the acti-zyme loading and the residence time. All experiments were replicated thrice and the average values were used. The standard deviations between the values varied between ±3%. Contour plots were generated in STATISTICA to represent the trends on the sewage physicochemical properties with increasing acti-zyme loading rates and retention times.

RESULTS AND DISCUSSION

Raw sewage characteristics

The raw sewage physicochemical characteristics obtained are indicated in TABLE 2. All the physicochemical characteristics were off in terms of the bodies that govern effluents disposal in Zimbabwe i.e. the Standards Association of Zimbabwe (SAZ), the Harare Municipality and the Environmental Management Agency (EMA) guidelines. This

TABLE 1 : 2^2 Factorial designs for determination of impact of acti-zyme loading and retention time on sewage physicochemical properties

Experiment no	Treatment combinations		Conditions	
	A (Acti-zyme loading rate)	B (Retention time)	A (g/m^3)	B (days)
1	-1	-1	35	7
2	1	-1	50	7
3	-1	1	35	40
4	1	1	50	40
5	0	0	42.5	23.5

TABLE 2 : Chitungwiza raw sewage characteristics in reference to effluent disposal guidelines

Parameter (Ave)	Chitungwiza sewage	SAZ Guidelines	Municipality Guidelines	EMA Guidelines	Remark
TKN (mg/L)	245		200	10	Off limit
BOD @20°C (mg/L)	557		1500	30	Off for EMA
TSS (mg/L)	608		600	25	Off limit
TDS (mg/L)	535	500		500	Off limit
E. Coli	TMC*				
EC @25°C (μs/cm)	3887	3000		1000	Off limit
Cl^- (mg/L)	833		500		Off limit
pH @25°C	9	6.0-9.0	6.8-9	6.0-9.0	Off limit
Coliforms (cfu/mL)	1x10? 11			?1000	
TP (mg/L)	52		30	?0.5	Off limit
SO_4^{2-} (mg/L)	1192		1000		Off limit
DO (% Saturation)	7			? 60	Off limit
Temperature (°C)	22		< 45	< 35	Off limit
COD (mg/L)	738	60	3000	60	Off limit

***Too many to count**

made the treatment of sewage using acti-zyme essential.

Effect of acti-zyme on sewage physicochemical characteristics

Effect of acti-zyme on pH

pH measures the H+ and OH- ions in sewage. On treatment of sewage with acti-zyme, the pH changed from being alkaline to almost neutrallinearly with an R^2 value of 0.94. The change in pH varied from 9.0 to 6.3 with increased acti-zyme loading and retention time in the sewage was 20% Figure 1. According to the ANOVA analyses with STATISTICA 12, increase in acti-zyme loading, increase in the retention time in the digester and their interaction had a positive effect on pH neutralization.

Effect of acti-zyme on TP

Total phosphates exist in sewage as phosphates. The TP in the sewage decreased linearly with increase in acti-zyme loading and the retention time with an R^2 value of 0.99 Figure 2. The percentage decrease was 19%. According to the ANOVA analyses with STATISTICA 12, increase in acti-zyme loading, increase in the retention time and their interaction had a positive effect on the TSS reduction.

Effect of acti-zyme on TKN

Total nitrogen (TKN) is the measure of the Kjeldahl nitrogen which comprises of ammonia, nitrates and nitrites. The amount of TKN in the sewage decreased linearly to 14.8 mg/L with increase in acti-zyme concentration and the retention time with an R^2 value of 0.96 Figure 3. The percentage decrease was 31%. According to the ANOVA analyses with STATISTICA 12, increase in acti-zyme concentration, increase in the retention time and their interaction had a positive effect on the TKN reduction.

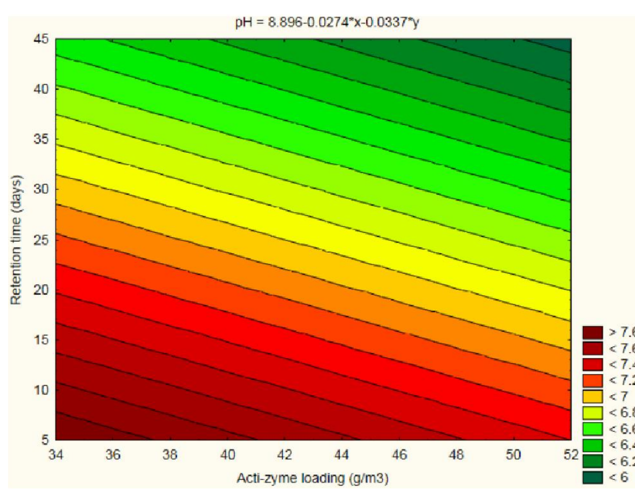

Figure 1: Effect of acti-zyme and retention time on pH

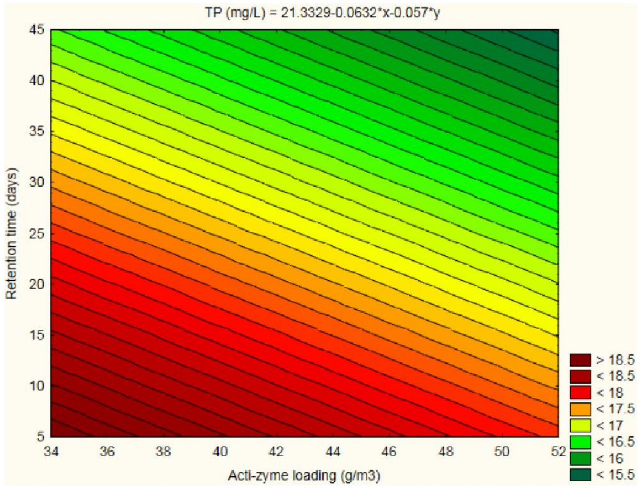

Figure 2 : Effect of acti-zyme and retention time on total phosphates concentration

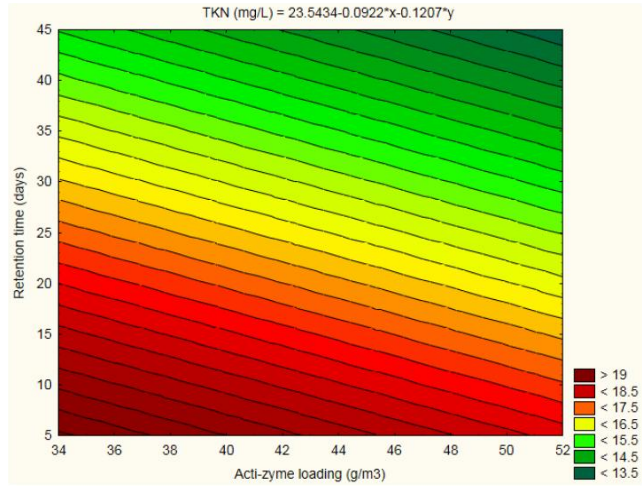

Figure 3 : Effect of acti-zyme and retention time on total nitrogen concentration

Effect of acti-zyme on BOD

Biochemical oxygen demand (BOD) refers to the amount of dissolved oxygen required by aerobic bacteria to break down organic matter. High TKN and TP values can also increase the BOD. The BOD in the sewage decreased linearly to 143.3 mg/L with increase in acti-zyme concentration and the retention time with an R^2 value of 0.94 Figure 4. The percentage decrease was 33%. According to the ANOVA analyses with STATISTICA 12, increase in acti-zyme concentration, increase in the retention time in the digester and their interaction had a positive effect on the BOD reduction.

Effect of acti-zyme on COD

The chemical oxygen demand (COD) measures the amount of organic pollutants in sewage. The COD in the sewage decreased linearly to 155 mg/L with increase in acti-zyme loading and the retention time with an R^2 value of 0.94 Figure 5. The percentage decrease was 49%. According to the ANOVA analyses with STATISTICA 12, only increase in acti-zyme concentration and increase in the retention time had a positive effect on the COD reduction but the interaction did not have a significant effect.

Effect of acti-zyme on TSS

The total suspended solids (TSS) measure the turbidity of water. The TSS in the sewage decreased linearly to 167.7 mg/L with increase in acti-zyme loading and the retention time with an R^2 value of 0.99 Figure 6. The percentage decrease was 52%. According to the ANOVA analyses with STATISTICA 12, increase in acti-zyme loading, increase in the retention time and their interaction had a positive effect on TSS reduction.

Effect of acti-zyme on TDS

Total dissolved solids (TDS) refer to the amount of mobile charged ions including minerals, salts and metals. The TDS in the sewage decreased linearly to 118.3 mg/L with increase in acti-zyme loading and the retention time with an R^2 value of 0.93 Figure 7. The percentage decrease was 26%. According to the ANOVA analyses with STATISTICA 12, only increase in acti-zyme loading and increase in the retention time had a positive effect on TDS reduction. However, their interaction did not have an effect.

Effect of acti-zyme on EC

Electrical conductivity refers to the amount of dissolved ions in water that have the potential to conduct electricity. The EC in the sewage decreased linearly to 2077.7 µS/cm with increase in acti-zyme loading and the retention time with an R^2 value of 0.97 Figure 8. The percentage decrease was 28%. According to the ANOVA analyses with STATISTICA 12, increase in acti-zyme concentration, increase in the retention time in the digester and their interaction had a positive effect on the EC reduction. The change in TDS and the change in EC had a linear correlation with an R^2 value of 0.94

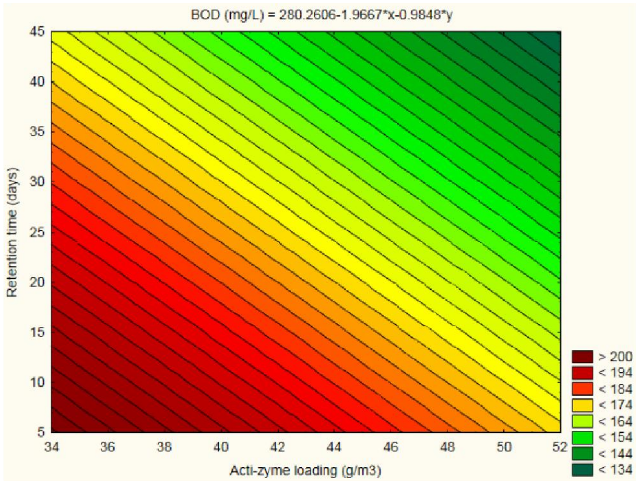

Figure 4 : Effect of acti-zyme and retention time on biochemical oxygen demand concentration

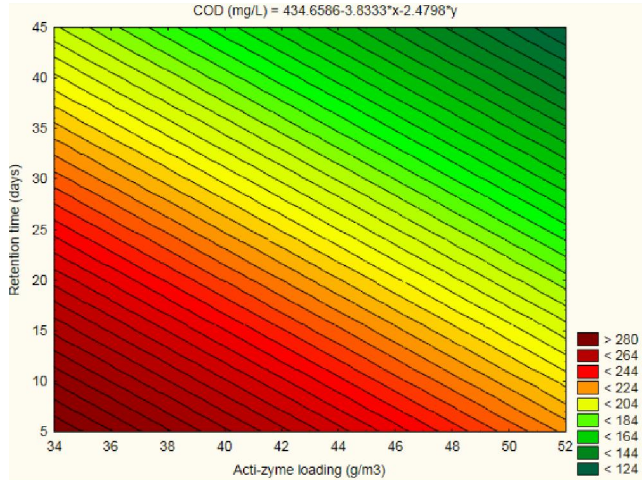

Figure 5 : Effect of acti-zyme and retention time on chemical oxygen demand concentration

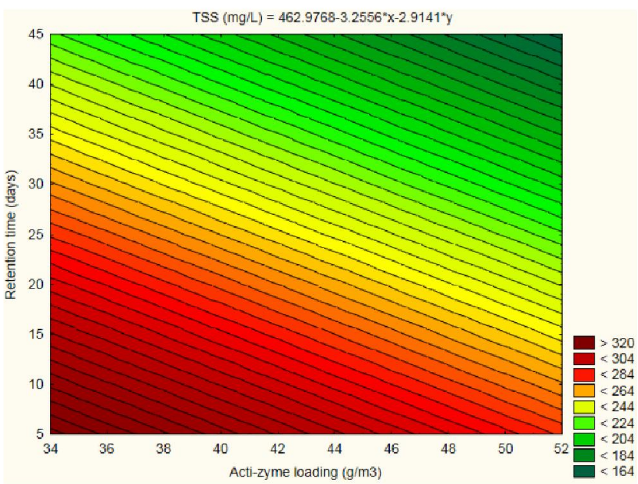

Figure 6 : Effect of acti-zyme and retention time on total suspended solids concentration

Figure 7 : Effect of acti-zyme and retention time on total dissolved solids concentration

and had a correlation shown in Equation 1, whilst the pH and the EC had a linear correlation shown in Equation 2 with an R^2 value of 0.98.

$$EC = 484.5pH - 922 \quad (1)$$

$$TDS = 0.0467EC + 23.252 \quad (2)$$

Effect of acti-zyme on Cl^- ions concentration

The Cl^- ions concentration in the sewage decreased linearly to 262.7 mg/L with increase in acti-zyme loading and the retention time with an R^2 value of 0.95 Figure 9. The percentage decrease was 56%. According to the ANOVA analyses with STATISTICA 12, increase in acti-zyme loading, increase in the retention time and their interaction had a positive effect on the Cl^- ionsreduction.

Effect of acti-zyme on SO_4^{2-} ions concentration

The SO_4^{2-} ions concentration in the sewage decreased linearly to 53.3 mg/L with increase in acti-zyme loading and the retention time with an R^2 value of 0.99 Figure 10. The percentage decrease was 91%. According to the ANOVA analyses with STATISTICA 12, only increase in acti-zyme loading, increase in the retention time had a positive effect on the SO_4^{2-} ions reduction.

Effect of acti-zyme on DO

Dissolved oxygen (DO) refers to oxygen saturation in the swage. The DO concentration in the sewage increased linearly to 87 mg/L with increase in acti-zyme loading and the retention time with an R^2 value of 0.99 Figure 11. The percentage increase was 222%. According to the ANOVA analyses with STATISTICA 12, increase in acti-zyme loading, increase in the retention time and their interaction had

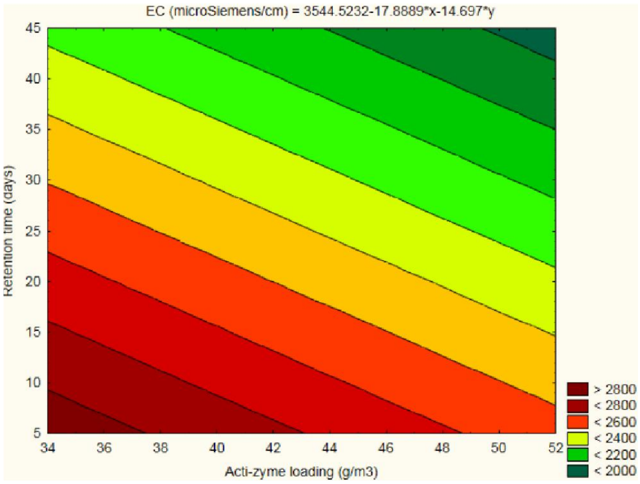

Figure 8 : Effect of acti-zyme and retention time on electrical conductivityJ

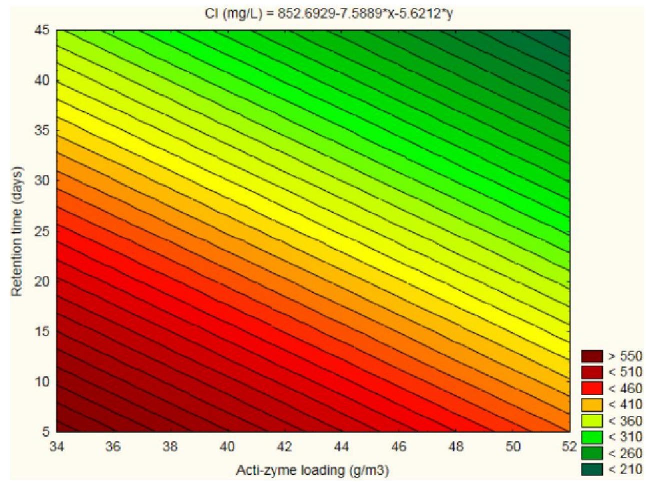

Figure 10 : Effect of acti-zyme and retention time on sulphate concentration

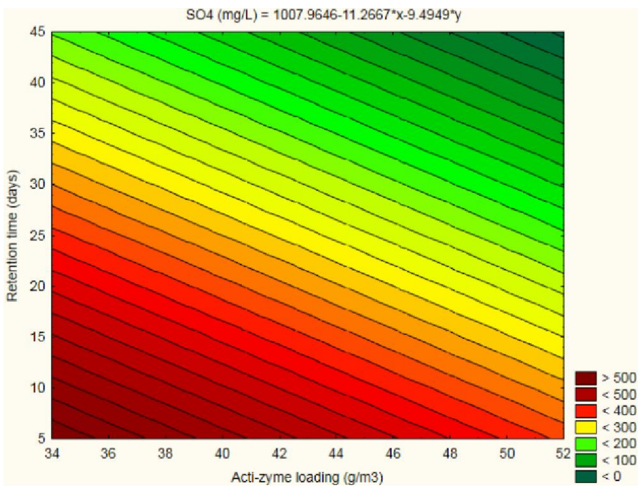

Figure 9 : Effect of acti-zyme and retention time on chloride ions concentration

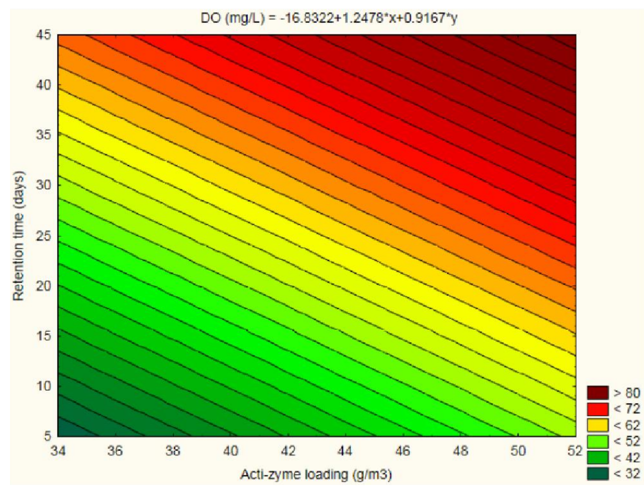

Figure 11 : Effect of acti-zyme and retention time on DO concentration

a positive effect on the DO increase. This was attributed to the removal of all contaminants due to the acti-zyme action.

Total E. Coli and coliforms content

The *E. Coli* in the sewage after treatment with acti-zyme was too many to count. In addition, the total coliforms value was too high, that was around 10^{11} coliforms. Despite, the *E. Coli* and total coliforms, the sewage effluent met the prescribed guidelines for sewage disposal either in accordance to SAZ, the Harare Municipality and EMA.

CONCLUSION

Acti-zyme effectively treats sewage removing all the wastewater contaminants to meet the required guidelines. However, chlorination must be done to remove the *E. Coli* and the total coliforms that will still be in treated effluent.

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