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Kinetic Studies on Dairy Wastewater Using Immobilized Fixed Bed Anaerobic Digester

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ABSTRACT

In any dairy plant, the quantity and characteristics of effluent is depending upon the extent of production activities, pasteurization to several milk products. The anaerobic digesters in the first phase of treatment, which is followed by high rate aerobic treatment, remain as the most common effluent treatment scheme for dairy plants. The Indian dairy industries is stated to have the growth at more than 15% and poised to cross the 150 million tones / annum. The requirement for milk and milk products is keep growing in steady pace, making a significant impact on the Indian agriculture domain. The dairy industries require large quantity of water for the purpose of washing of cans, machinery and floor, the liquid waste in a dairy originates from manufacturing process, utilities and service section. So there is every need to reuse the waste water generated with proper and efficient treatment methods. Here the source of waste generation is a mixed sludge from dairy processing unit. The present study, thus initiated, for evaluating a need based experimental work on anaerobic digester incorporated with immobilized poly urethane foams system for treating dairy effluent with four weeks of harvesting. The kinetic parameters are estimated using the experimental data to develop a model. Empirical relations were generated for the characteristics like COD, SCOD, BOD, TDS, and TSS using modeling equations.

Key words: Kinetic parameters, COD (chemical oxygen demand), SCOD, BOD (biological oxygen demand), TDS (total dissolved solids), TSS (total suspended solids).

INTRODUCTION

Water management in the dairy industry is well documented, but effluent production and disposal remain a problematic issue for the dairy industry .To enable the dairy industry to contribute to water conservation, an efficient and cost-effective treatment technology has to be developed. To this effect anaerobic digestion offers a unique treatment option to dairy industry. Not only does anaerobic digestion reduce the COD of an effluent, but little microbial biomass is produced. The biggest advantage is energy recovery in the form of methane and up to 95% of the organic matter in a waste stream can be converted into biogas[13] .Many high-rate digester designs are currently available and some have successfully been used for the treatment of dairy effluents. A full-scale up flow anaerobic sludge blanket digesters in uses world-wide [12]. The fixed-bed digester is another high-rate digester that has been used for the treatment of dairy effluents. A high-rate combination design, using the up flow anaerobic sludge blanket (UASB) and the fixed-bed digester types, was developed [1]. This design was successfully used to treat landfill leachate and baker's yeast factory effluent. Landfill leachate and yeast effluent both are having high COD concentrations and both are difficult to degrade biologically. On the other hand, dairy effluents are fairly easily biodegradable, since they consist mainly of diluted dairy products. Thus, the aim of this study was to evaluate the use of anaerobic digester (fixed film fixed bed) in the treatment of a dairy effluent and to study the kinetics of other parameters [10] .The diary waste is collected from the final milk processing unit. Nearly 30-40m^3 of waste water is produced daily in this dairy industry. A graphical Model was also developed to predict total COD level in dairy wastewater, providing an important design parameter for implementation of fixed-film anaerobic digestion systems [5]. The high strength industrial waste stream can be treated in such anaerobic system for system efficiency of 80-90% COD reduction. The incorporation of immobilized microbial support systems in the reactors to have attached-growth systems of microorganisms will enable anaerobic systems to perform well with much more process stability.

MATERIALS AND METHODS

The experimental setup consists of Immobilized Fixed Bed Anaerobic digester having effective reactor volume of 2.0 lit. The experimental model is of 1.5 lit effective volumes Immobilized digester system is fed by diluted Dairy wastewater [6]. Biomass sludge was activated by aerating the organisms which was fed in to anaerobic digester and the harvesting was carried up to 28 days. Mixed vegetable waste is used as a nutrient for the development of micro organisms [2]. Samples were collected from a local market and macerated using a domestic food blender so that the wastes had been reduced to the smallest possible sizes(125-250μm) and stored in a refrigerator at 4°C.1 gram of mixed vegetable waste (on wet basis) is added per 1 liter of the waste water to be treated. The type of samples collected were Brinjal, cabbage, carrot, potato, pumpkin, tomato in their rotten form [8]. Each of these vegetables is added in equal quantities and grinded [1]. The reactor was observed to attain the steady state conditions after four weeks with an average COD removal of 80% to 90%.After the Inoculum development step, the influent was fed by the upper part of the immobilized digester at six different theoretical hydraulic retention times (HRT) in a decreasing order of 6, 5, 4, 3, 2 and 1 days, which corresponded to average organic volumetric loading rates (Bv) of 26,36,40,74,152,201,226 mg/L of COD .The experiment was run for five batches[7]. The operating conditions are interpreted for the parameters of organic loading rate (Bv, mg/L) COD, BOD and SCOD (filtered COD). Also the parameters like TDS and TSS for every operating batch were observed. Values are averages of 3 determinations taken over 3 weeks after the steady-state conditions had been reached [4]. The differences between the observed values were less than 3% in all cases. The features and characteristics of influent used are shown in Table1 which lists the average values and standard deviations of the separate analysis carried out.

RESULTS AND DISCUSSIONS

Mathematical Model: The success of any biological treatment plant lies in the kinetics of the process as they determine the dimensions of the unit operation and dictates the control parameters and operating values. The experimental observations and their kinetic interpretation are used to evaluate the substrate utilization (COD removal) kinetics of the anaerobic process of treatment having attached growth system [11]. The removal of COD is envisaged for the maximum percentage, with necessary operating variables of influent COD, SCOD, TDS, TSS, and HRT. The loading rate of organics on the biological system, the composition of biological systems and the active status of the biological systems are correlated to explain the process of COD removal or in terms of (substrate) utilization [9]. Better the utilization of organics by the biological system for their energy requirement (during which they also stabilize most of the unstabilized waste constituents) better the COD removal. According to the results obtained by regression analysis, logarithmic type functions appear to describe the effect of *B*v on the fractional removal efficiency [14]. The general mathematical expression that relates *B*v and the fractional removal efficiency is given by the following equation-

$$Ef = K1[\ln(1/Bv)] + K2(1) \qquad (1)$$

Where *E*F is the fractional removal efficiency at a given value of *B*v, *K*1 is a dimensionless empirical constant and *K*2 is another empirical constant equivalent to the *E*F value obtained when *B*v is equal to unity and, therefore, ln *(*1/*B*v*)* is equal to zero. The values for the empirical constants *K*1 and *K*2 obtained in the experiment and the correlation factors are summarized in Table 2. Equation 1 is only valid within the experimental range of *B*V studied (226-26 mg/L COD dm).The effect of the organic volumetric loading rate on the effluent COD is illustrated in Fig 1. An increase of *B*V in the range from 26 to 226 mg/LCOD caused virtually a linear increase in the fractional removal efficiency of COD from 10 % to89%. When *B*V increased from 26 to around 226 mg/L COD, the effluent COD concentration increased moderately from 26 to 74 mg/L. Hence, the process was capable of assimilating a considerable increase of the organic loading without failure. The following empirical relationship was found between *B*V and effluent COD-

$$EfCOD = 0.0044Bv + 1.0081 \qquad (2)$$

Likewise, empirical relations were developed for TDS, TSS, BOD parameters whose fractional removal efficiency decreased with the increase of Bv .In TDS and TSS, the rate of removal efficiencies proceeded at a slower pace, particularly in case of TDS. Since the organic matter is the main substrate for anaerobes to degrade, no significant removal rates were seen in TDS and TSS .The BOD levels decreased at a satisfactory rate. The fractional removal efficiency equations are obtained as follows-

$$EfSCOD = 0.0044Bv + 0.9998 \quad (3)$$
$$EfBOD = 0.0036Bv + 0.8679 \quad (4)$$
$$EfTDS = 0.0016Bv + 0.4254 \quad (5)$$
$$EfTSS = 0.0013Bv + 0.2813 \quad (6)$$

The plot of loading rate Bv versus the fractional efficiency is made to study the COD and as well independently for other parameters like SCOD, BOD, TDS, TSS. The plots of drawn curves are shown in the Fig. 2, 3, 4 and 5.

CONCLUSION

According to the results obtained elimination of COD increases with the no. of days up to 45 mg/L .More than 85% COD removal efficiency was achieved in the reactor with influent COD concentration of 226mg/L. The empirical equations for removal efficiencies of other characteristics were developed. The results from this study proved the immobilized Fixed Bed anaerobic digester flexibility and excellent performance for treating domestic and easily biodegradable wastewater such as dairy wastewater.

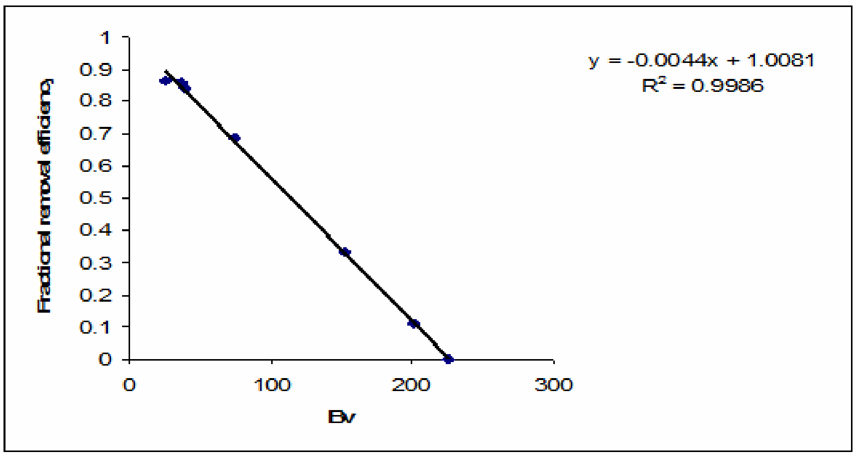

Fig.-1: Fractional removal efficiency vs Bv.

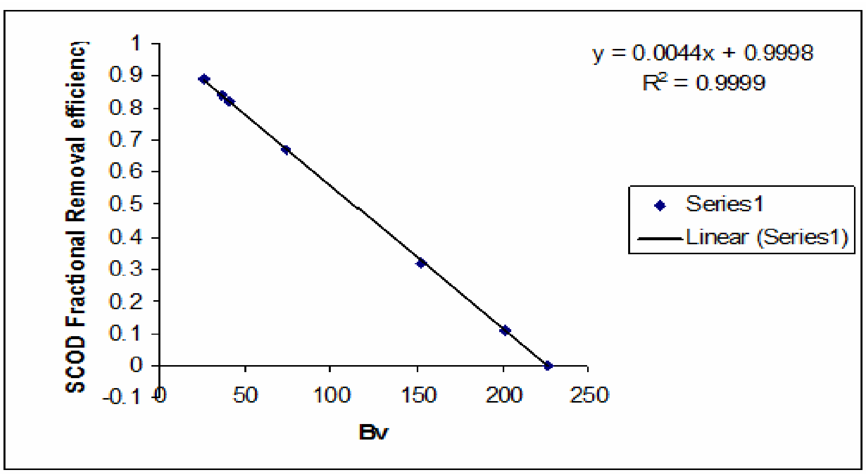

Fig.-2: Fractional removal efficiency graph of Bv vs SCOD.

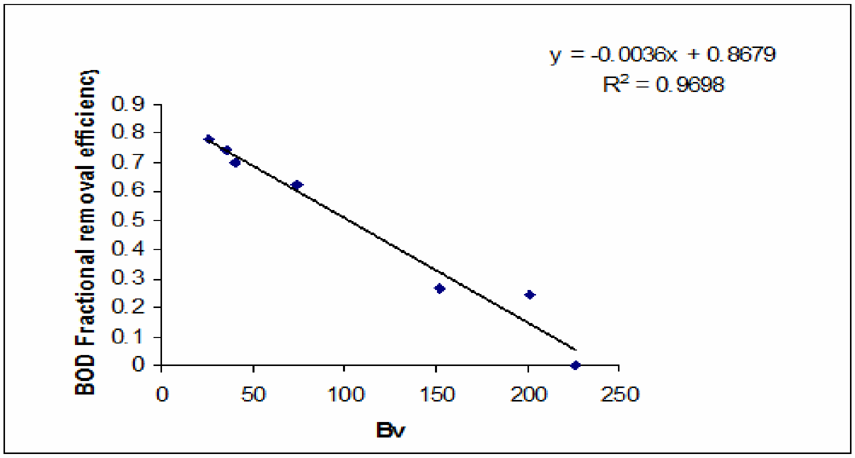

Fig.- 3: Fractional removal efficiency graph of Bv vs BOD.

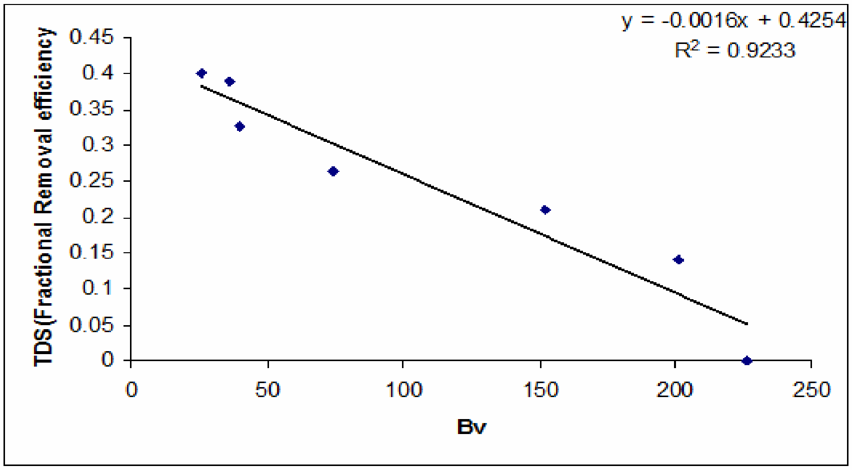

Fig.- 4: Fractional removal efficiency graph of Bv vs TDS.

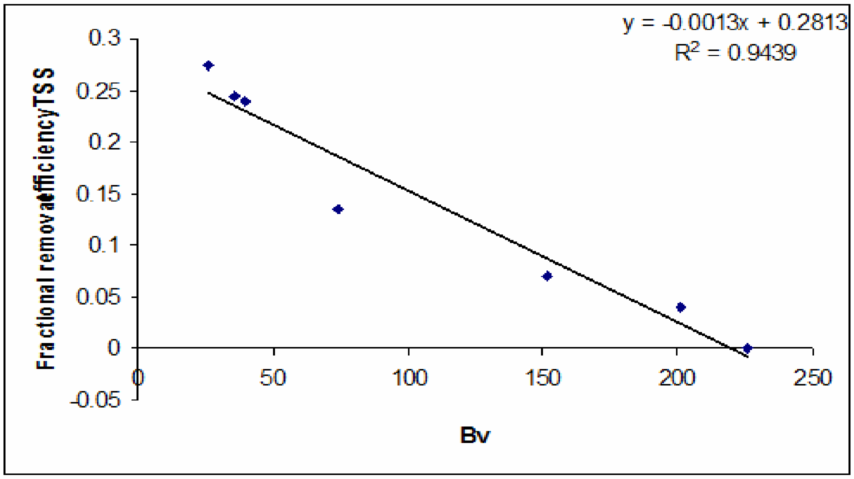

Fig.-5: Fractional removal efficiency graph of Bv vs.TSS

Table-1: The influent characteristics of dairy waste water.

Influent characteristics	Values (mg/L)
COD	304
TS	1688
TDS	1393
TSS	295
BOD	81
pH	7.6

Table-2: The empirical constants K1 and K2, and the regression coefficients of the parameters that were studied.

Parameters	K1	K2	R^2
COD	0.0044	1.0081	0.9986
SCOD	0.0044	0.9998	0.9990
TDS	0.0016	0.4254	0.9233
TSS	0.0013	0.2813	0.9439
BOD	0.0036	0.8679	0.9698

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