Development of Packed Bed Column for Treating Dairy Waste Water

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Abstract— *This study presents the treatment of dairy waste water using laterite grains. The treatment is carried out in a fabricated column packed with soil grains. The waste water treatment is carried out with different packing media i.e. Laterite Grain (LG), Acid activated Laterite Grain (AALG). The performances with varying flow rate and retention time are examined. The properties of the wastewater is tested for both physical and chemical properties like turbidity, TDS,TSS, BOD and COD are estimated by suitable laboratory procedures. The effective optimum flow rate is 8.3 ml/min and retention time is 45 min for LG and 30 min for AALG. Comparing LG and AALG, AALG is better for packed bed reaction with more than 85% of removal efficiency. Experimental data was fitted in two models namely Yoon Nelson and Adam Bohart. Yoon Nelson model was most satisfactory for packed bed reaction using Laterite grains. And the values of the model parameters were evaluated and analyzed.*

Keywords— LG, AALG, Yoon Nelson model and Adam Bohart model

I. Introduction

Environmental pollution due to rapid industrialization is a modern problem since last five decades. Compared to commercial or domestic waste water industrial water contains much more pollutants. The properties waste water generated from various industries are differing from each other and also the processing method also varies from one industry to other. So such waste water produced form industries are very difficult to treat compared to domestic waste water treatment. Compared to all food sector has the high amount of consumption of water and also the biggest producers of effluent. Dairy industry is the one of the best example of this sector. In India dairy industries is the one of the major food industry, and have first position in production of milk among the maximum milk producing nation. Per year milk producing industry generates about 3.739 to 11.217 million cubic meters of waste. In dairy industry milk is processed and various products of milk are manufactured. Dairy industry, in which the cleaning tanks, homogenizers, heat exchanger and other equipments cause large amount of effluent with high level of organic load. Basically the organic load is constituted by milk and milk products, detergents, inorganic salts, sanitizers used for washing leads to an effluent with high level of COD and BOD. The characteristics of waste water mainly depend on amount of milk processed and type of product produced. Industrial waste water treatment is mainly based on the concentration, toxicity, quantity, amount of biodegradable materials etc. The waste water received by the land affect the soil structure and quality and the part of the waste water can also leach to underlying ground water and affect the water quality. The main reason of the pollution is the poorly treated waste water; it is mainly due to poor design, operation and treatment system. There are so many studies are going for cheaper treatment and easy method for disposal and utilization of waste water from milk processing unit in India and other countries. In most of the industries the water is discharged with partial treatment and also industries does not have any methods of recycling the water for other purposes[1]. So in such situation findings from the present study become useful for milk processing industries to plan a proper disposal method for avoid pollution as well as environment clean The methods treatment consists of any one or more of the processes like preliminary treatment, physical treatment, chemical treatment and biological treatment. In new technology after the biological treatment process in order to remove specific types of residuals which are not removed through biological process. The methods like chemical oxidation and adsorption by granular activated carbon removes organic matters and filtration removes suspended or colloidal solids [3]. The study mainly aims to develop a cost effective treatment method for treating dairy waste water.

II. Objectives

The objectives of this study were

- study the performance of reactor with different packing media i.e.; Laterite Grain(LG) and Acid Activated Laterite Grain(AALG)
- The performance with varying flow rate and retention time are examined and will find out which one is best

III. Materials and Methods

A. Laterite Grain:

Laterite grain is collected from Attingal region of Trivandrum, Kerala .To remove undesirable impurities the collected soil is washed several times with tap water, then the soil is dried. Then the soil is crushed to get the required size. Then the obtained soil is washed 20-30 times to remove the red colour and finally dried and kept in a air tight container to avoid further contact with moisture. To prepare acid activated Laterite (AALG) grain 50 gm of Laterite grain is selected and 100 ml of 0.2 HCl solutions were taken into 250 ml glass beaker. Then the acid-soil mixture is mechanically agitated with 250 RPM for 2 hours and the mixture is kept at room temperature for 24 hours. Then the soil grains are taken and washed with distilled water. This is carried out till the pH of the wash water reached about 6.5 and AALG was sun dried and kept in an air tight container.

B. Collection of Sample Water:

Sample water was collected from nearby dairy industry and preserved at 4^{o}C to prevent any change in physico-chemical characteristics. The physico-chemical characteristics of wastewater were determined as per procedures described in Standard Methods and initial characteristics of effluent are examined.

C. Experimental Setup:

The experiment is carried on a glass column of 40 mm diameter and 600 mm total height. The column is packed with the required quantity of soil between two supporting layers of glass wool. The waste water is fed into the column in the down flow direction and the experiment is conducted with different flow rate and retention time.

D. Column Dynamics Study:

The performance of sorption of cations through a column was analyzed by Thomas, Yoon Nelson and Adam- Bohart models. These models are starting from a concentration ratio of Ct/Co>0.1 means 10% breakthrough until Ct/Co>0.90 means 90% breakthrough for adsorbate by considering the safe water quality standards.

E. Yoon Nelson model:

It is the simple theoretical model developed by Yoon Nelson for investigate the break through behaviour of adsorbent in the column. It is expressed as the following equation,

$$\ln \frac{C}{Co-C} = Kt - \tau K$$

Where C, Co the effluent and inlet solute concentrations (mg/l),K is the rate constant, τ is the time required for 50 percent adsorbate break through and t is sampling time[2].

F. Adams- Bohart model:

This model was established based on the surface reaction theory and this model assumed that equilibrium is not instantaneous. The mathematical equation of the model is expressed as,

$$ln\ \frac{C}{Co} = K_{AB} \mathrm{Co\ t} - K_{AB}\ \mathrm{No}\ \frac{z}{\mu_0}$$

Here, K_{AB}(l/min.mg) is the rate constant, z (cm) is the bed depth, No (mg/l) is the maximum adsorption capacity per unit volume of adsorbent column and μ_0 (cm/min) is the linear velocity of influent solution [2].

G. Material Analysis:

Scanning Electron Microscopy (SEM) analysis and Energy Dispersive Spectroscopy (EDS) were carried in Laterite grain. SEM is carried out for finding out the surface morphology of the sample and EDS is carried out for the chemical composition of sample.

IV. RESULTS AND DISCUSSION

A. Initial Properties of Dairy Wastewater:

The samples were collected was analyzed for Turbidity, Suspended solids, Dissolved solids, BOD and COD. From the result mentioned in table 1 it was observed that all parameters are not in the permissible limit. So the waste water is not suitable for discharging into the surface water bodies.

Parameters	Raw Water Sample Values
Turbidity (NTU)	762
Total Dissolved Solids(Mg/L)	1450
Total Suspended Solids(Mg/L)	2570
BOD(Mg/L)	1198
COD(Mg/L)	2900

Table 1: Properties of Raw Water Sample

B. Optimization of Flow Rate:

The experiment is conducted with different flow rate (4.16, 5.5, 8.3, 16.6 and 33.3 ml/min). Packed bed reaction with different flow rate is conducted in both LG and AALG. From the result it is observed that all the parameters are reduced with different flow rate. But at 8.3 ml/min more than 70% of removal efficiency is obtained almost all the parameters like COD, BOD, TS and turbidity for both LG and AALG. So 8.3 ml/min is considered as the optimum level. The removal efficiency of parameters for both LG and AALG are shown in the fig 1 and fig 2.

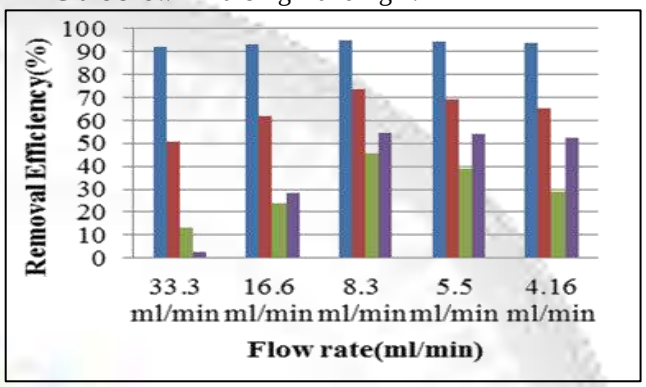

Fig.1: Removal efficiency of LG

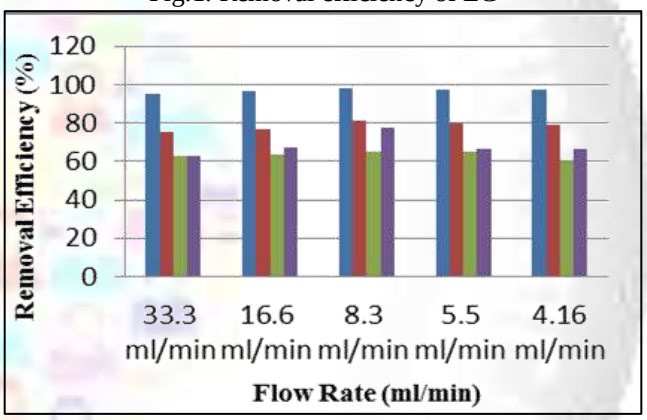

Fig. 2: Removal efficiency of AALG

C. Optimization of Retention Time:

The experiment is conducted with different retention time (15, 30, 45, 60 and 75 min). Packed bed reaction is conducted with LG and AALG. Almost all the parameters are removed in different retention time. For Laterite grain at 45 min retention obtained maximum removal efficiency of all the parameters after than the parameters are increasing so it's considered as the optimum level. And for activated soil grains better removal efficiency is obtained at 30 min removal efficiency after that the parameters are slightly increasing so it's considered as the optimum level. The removal efficiency of parameters for both LG and AALG are shown in the fig 3 and fig 4.

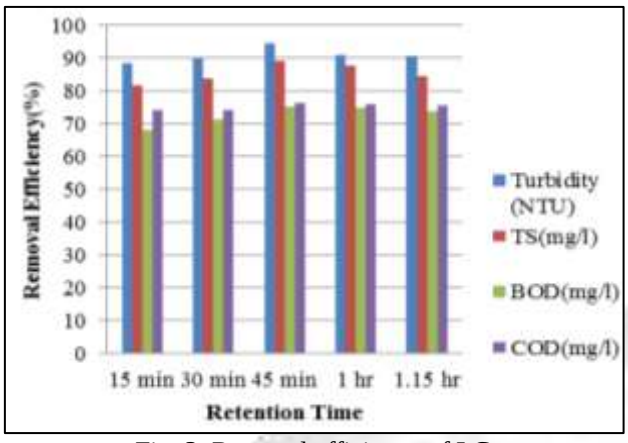

Fig. 3: Removal efficiency of LG

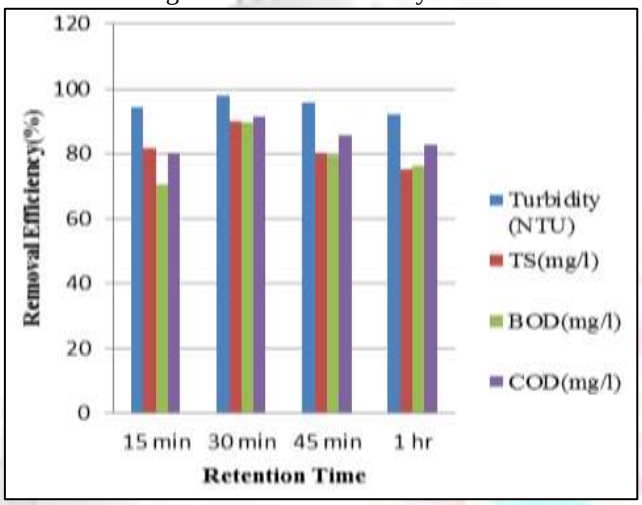

Fig. 4: Removal efficiency of AALG

D. Column dynamics study:

The Yoon Nelson model is calculated for different flow rate for COD reduction. Yoon nelson model was much satisfactory with R2 value for both LG (R2=0.802) and AALG (R2=0.881) for different flow rate. Yoon Nelson parameters for both LG and AALG are shown in the table 3. Yoon Nelson model is more satisfactory than Adams-Bohart model for packed bed reaction and Adams- Bohart model is calculated for different flow rate for COD reduction. Compared to Yoon Nelson model Adams Bohart model is not that much satisfactory with R2 value for both LG (R2=0.791) and AALG (R2=0.824). Adams- Bohart model parameters for both LG and AALG are shown in table 4.

Parameters	LG	AALG
K_{AB} (ml/min/mg) x 10^{-4}	0.026	0.017
No (mg/l)	11.85	317.31
R^2	0.791	0.824

Table 2: Adam Bohart Model Parameters

Parameters	LG	AALG
K (min^{-1})	0.055	0.018
T (min)	2.07	73.27
R^2	0.802	0.881

Table 3: Yoon Nelson Model Parameters

E. Material analysis:

On SEM images, can easily recognize surface morphology of Laterite grains. Before reaction the surface of Laterite was quite rough and after reaction the impurities are distributed tightly all over the surface. In the untreated specimen's photomicrograph, large void spaces are present, whereas the void space distribution in the activated specimens seems to be more uniform. The SEM images of Laterite grain and AALG are shown in the fig 5 and fig 6. And EDS of Laterite grain gives the chemical composition of LG. The analyses of Laterite grain indicate that iron and aluminium are the major component. It may be due to the mechanical weathering of parental rock. It also contains carbon, oxygen and silicon. The result obtained from EDS is shown in table 4.

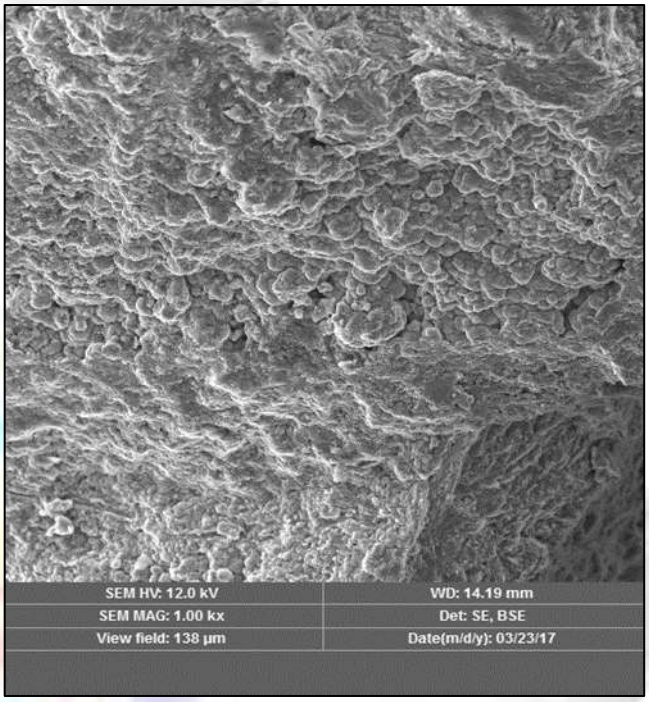

Fig. 5: SEM image of LG

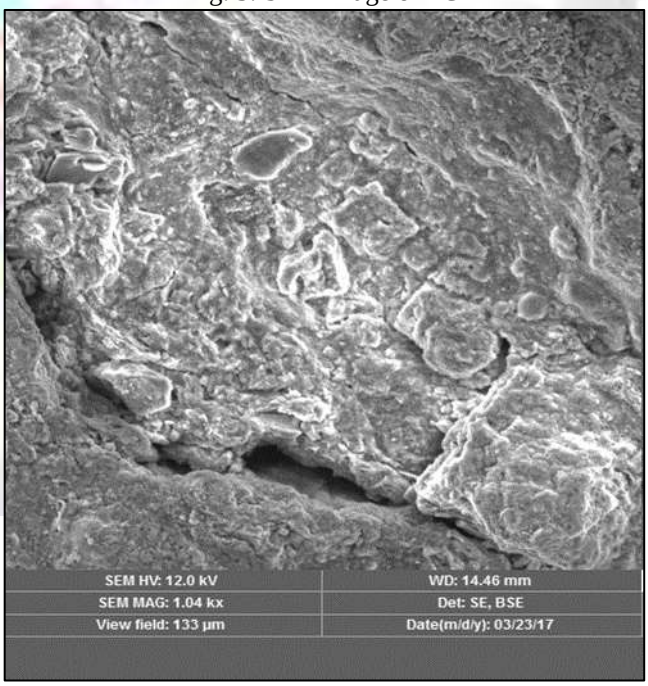

Fig. 6: SEM image of AALG

C (%)	Al_2O_3 (%)	SiO_2 (%)	FeO (%)
8.92	18.69	9.93	62.47

Table 4: Result Obtained From EDS

V. CONCLUSION

Packed bed reaction is effective method for treating dairy waste water while laterite grains are used as packing material. The experiment is carried out with different flow rate and detention time. Packed bed reaction is effective for both LG and AALG. But AALG is better for packed bed reaction because of its more porous structure due to acid treatment. Using LG more than 65% removal efficiency is obtained for almost all the parameters. And for AALG more than 80% of removal efficiency is obtained for almost all parameters. The effective optimum flow rate is 8.3 ml/min and retention time is 45 min for LG and 30 min for AALG. Experimental data was fitted in two models namely Yoon Nelson and Adam Bohart. Yoon Nelson model was most satisfactory for packed bed reaction using Laterite grains.

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