Jr. of Industrial Pollution Control 20(1) (2004) pp. 7- 16

DETERMINATION OF BIO-KINETIC COEFFICIENTS FOR DAIRY WASTE WATER

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Key words : Biokinetics, Dairy wastes, HRT, OLR

ABSTRACT

Due to the increase in demand for milk and milk products many dairies of different sizes have come up in different places. These dairies collect the milk from the producers, and then either simply bottle it for marketing, or produce different milk foods according to their capacities. Large volumes of wastewater originate due to their different operations and they contain high amount of pollution load, which will affect the receiving streams seriously. In this study activated sludge process was used to treat dairy wastewater. The settled dairy wastewater was treated by operating a bench-scale continuous flow stirred tank reactor without solids recycle at θ_c varying from 1 to 6 days. The bio – kinetic parameters were evaluated using the observational data at steady state conditions. The percentage of BOD removal ranged from 67 to 90 under steady state conditions, indicating there by that settled dairy wastewater could be treated by activated sludge process. The bio – kinetic parameters obtained from the present study can be used in the design of activated sludge process, which will be more scientific and reliable.

INTRODUCTION

Rapid industrialization causes the liberation of a tremendous quantity of wastewater. Pollutants from both domestic and industrial wastewater tend

to create un favorable ecological conditions in every walk of life. The present study deals with wastewater generated from dairies and determination of its bio-kinetic coefficients. With the increase in demand for milk and milk products, release of wastewater from dairy industries is also increasing. Waste water generated from milk processing and milk products manufacturing produces highly organic waste with huge volume in accordance with the demand. Dairy waste is basically biodegradable produces an undesirable odour and contains an appreciable quantity of oil. Fresh Dairy waste is highly alkaline and turns to acidic due to the fermentation of lactose to lactic acid. Due to these properties chemical treatment methods may not appropriate. Also dairy waste contains sufficient nutrients for biological growth, biological treatment methods are considered more ideal and economical.

If untreated dairy waste is let into water bodies it will pollute water, there by causing several diseases to humans and animals utilizing this waste. Hence it is required to treat this wastewater and to obtain effluent free from impurities. Activated sludge process can be employed very effectively for a complete treatment of dairy waste. Design of such biological treatment can be made more reliable by using biokinetic coefficients of that particular waste.

The prime objective of this study is to determine biokinetic coefficients Ks, k, Y, k_d, μ_{max} for the design of activated sludge process, to treat dairy wastewater by conducting aerobic biological treatment studies in the laboratory using a bench scale reactor without solids recycle system

MATERIALS AND METHODS

Activated sludge process

It involves the production of an activated mass of microorganisms, capable of aerobically stabilizing the waste. The organic waste is introduced into the reactor, where an aerobic bacterial culture is maintained in suspension. The bacterial culture carries out the conversion of organic matter to less harmful constituents under aerobic conditions. After a specified time interval the mixture of old cells and new cells are passed into a settling tank where the cells are separated from treated wastewater.

In the design of activated sludge process, parameters like mean cell residence time, F/M ratio, Volumetric loading, hydraulic retention time, oxygen requirements, sludge production and control and solids separation are considered to be important.

Mean cell residence time

It indicates the residence time of biological solids in the system and is expressed the ratio of the mass of cells in the reactor relative to the mass of cells leaving the system per day.

In continuous flow stirred tank reactor without solids $\theta_c = \theta$

$$\theta_c = VX/QX = \theta \quad (1)$$

Where V is the volume of the reactor in m^3
Q is the rate of flow of waste into the reactor in m^3/day

Food (F) to micro organism (M) ratio

It is a manner of expressing BOD loading with regard to the microbial mass in the system.

$$F/M = So/\theta X = Qso/VX \quad (2)$$

So = Influent BOD, mg/l

F/M ratio for an activated sludge plant is the main factor controlling BOD removal. Lower the F/M ration higher will be the BOD removal in the plant. (E.g. extended aeration)

Volumetric BOD loading

Another important loading parameter is volumetric loading, which is defined as the BOD5 load, applied per unit volume of aeration tank. This loading is also called organic loading.

Hydraulic retention time (θ)

Hydraulic retention time is defined as the time of a particle of waste water spend in the reactor $\theta = V/Q$

Biological treatment kinetics

To design and operate a biological treatment system efficiently it is necessary to understand the importance of biokinetic parameters, which involved in the process.

The main purpose of kinetic is

1. To develop micro organisms and substrates balances
2. To find effluent microorganism and substrate concentration
3. To develop process design parameters
4. To ascertain the process performance and the stability

The continuous flow stirred tank reactor without solids recycle system (Fig 2) is used for the analysis.

Fig1. CFSTR without solid recycle

Accumulation = inflow-outflow net+ growth (change)
Material mass balance across the system can be used to determine the substrate concentration and microorganism in the effluent as given by the equations 3 and 4.

$$X = \frac{Y\,(So-S)}{1+Kd\theta} \quad (3)$$

$$S = \frac{Ks\,(1+Kd\theta)}{\theta(YK-Kd)-1} \quad (4)$$

Waste sampling and characterization

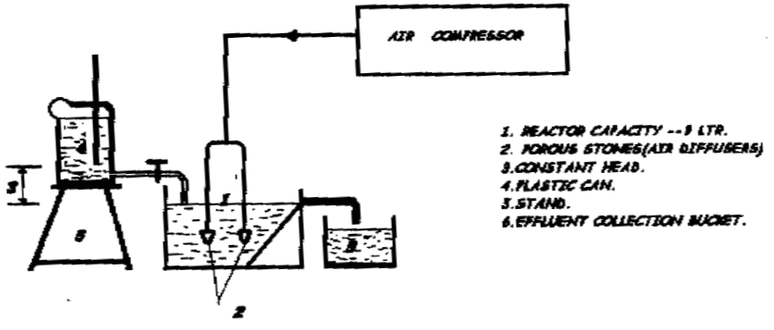
The waste investigated in this study was the dairy wastewater taken from the Coimbatore district co-operative milk producers union Ltd in Coimbatore.

Dairy waste was obtained from the collecting well prior to treatment at various periods was conveyed immediately to the laboratory and stored in deep freezer.

In order to decide the type of treatment to be given to the waste, the analysis of dairy wastewater carried out as per the standard methods.

Apparatus and methodology

The bench scale completely mixed continuous flow activated sludge reactor, 9lit. Capacity without solids recycle system was fabricated. Five hours settled dairy wastewater, seeded with activated sludge obtained from a running aerated lagoon was fed into the reactor through a constant head tank with flow regulation facility. Compressed air was introduced into the reactor and DO concentration in the reactor was never allowed to drop below 3 mg/l. A schematic diagram of experimental set up is shown in fig 3.



EXPERIMENTAL SETUP

The daily influent flow rate was calculated based on the volume of the reactor and the mean cell residence time. i.e., $\mathbf{Q=V/\theta_c}$.. The reactor was operated under different θ_c varying from 1 day to 6 days with MLVSS varying from 772 mg/l to 1386 mg/l. The activated sludge system was operated until stabilized condition was achieved as represented by sludge growth on a day to day's basis and effluent BOD remained constant.

The parameters such as influent and effluent substrate concentration in terms of BOD, pH, MLVSS, Mean cell residence time and flow were measured during the study.

Determination of bio-kinetic coefficients

Based on the Experimental Results, Bio-kinetic coefficients were determined. The following modified monad equations are used to develop the kinetic coefficients.

$$\frac{1}{U} = \frac{Ks}{K}\,\frac{1}{S}+\frac{1}{K} \quad \text{----------} \quad (5)$$

$$U = \frac{S_0 - S}{\Theta X} \quad \text{----------} \quad (6)$$

$$\frac{1}{\Theta_C} = YU-k_d \quad \text{----------} \quad (7)$$

The values for the reciprocal of specific substrate utilization rate (1/U) were plotted against the reciprocal of effluent BOD (1/S) and substrate removal kinetics were evaluated using the plot as shown in fig 4.

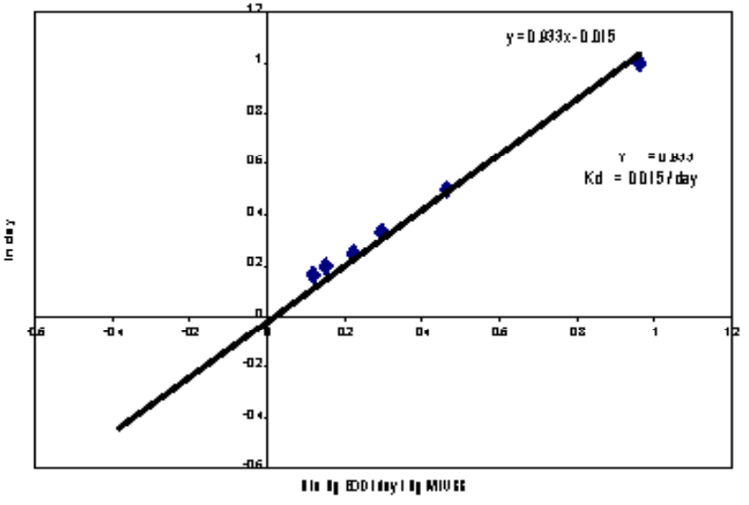


Fig.3 - Sludge Production relationship

The slope of the straight line was Ks / k and intercept was 1/k. The values of the reciprocal of the mean cell residence time ($1/\theta_c$) were plotted against specific substrate utilization rate (U) as shown in fig 5. The yield coefficient Y was determined from the slope of the line. The endogenous decay coefficient (k_d) was obtained from the intercept k_d= -C.

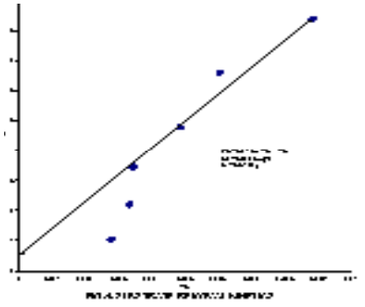


Fig. 4 - Substrate removal kinetics

RESULTS AND DISCUSSION

Dairy waste characterization

The characteristics 5 hours-settled wastewaters were analyzed and the results are presented in table.

Primary settling

The dairy wastewater was retained in a container and the total solids and suspended solids removal efficiencies were determined for 5 hrs. The Results are presented in table2.

The removal efficiencies and the detention time for total solids and suspended solids are given in table2.

The suspended solids removal was 87.69% after 5hrs. Hence for this Experimental study the wastewater was pretreated by settling for 5hrs and the supernantant was subjected to further Biological treatment.

TABLE - 1

Characteristics of 5 hrs settled dairy wastewater

Parameters	Value
pH	7.2
Colour	Milk white
Solids	
Total	2300
Suspended	820
Volatile	1480
5 day BOD	1050
COD	3600
Sulphates	535
Chlorides	72
Alkalinity	480

All values except pH are in mg/l

TABLE - 2
Total solids and suspended solids removal from primary settling

Detention time in hrs	% Of total solids removal	% Of suspended solids removal
1	17.59	44.23
2	48.17	53.46
3	49.23	75.00
4	50.38	81.15
5	51.92	87.69

Bio-kinetics

The experimental results obtained by conducting experiment using bench scale reactor without solids recycle for steady state condition are presented in table3.

TABLE - 3
Summary of steady -state runs with settled dairy wastewater

θ_C=θ	Flow	S_0	S	X	BOD removal	F/M ratio
Day	Lit/day	mg/l	mg/l	mg/l	Efficiency	D^{-1}
1	9	1100	358	772	67.45	1.42
2	4.5	1102	298	868	72.95	0.63
3	3	1146	290	987	74.69	0.39

The graph between 1/U and 1/S was plotted and substrate removal kinetics Ks and k were evaluated as shown in fig 4. The values of Ks and k were 876.76 mg/l and 2.5 /day respectively. The graph between ($1/\theta$c)

and U was plotted to obtain Y (Slope) and Kd as shown in fig 5.The values of Y and Kd were 0.9333 and 0.015/day respectively.

Half-velocity constant (Ks)

Half velocity constant is defined as substrate concentration at one half of the maximum growth rate. $\mu=\mu_{Max}\, S/K_{s+}S$

Increased value of Ks shows the decrease in specific growth rate. It reveals that there is only limited amount of substrate and nutrients in the wastewater due to the intermittent flow conditions and the fluctuations in the concentration of the wastewater.

Yield coefficient (Y)

Yield Coefficient is defined as the ratio of the mass of cells formed to the mass of substrate consumed.

The value of yield (Y) is virtually constant for a wide variety of substrate treated aerobically. The Y value obtained for dairy waste water is 0.9333 and this higher value may be due to the fact that aerobic break down of organic substrate would have released more energy favouring the growth of cells.

Substrate removal rate Coefficients (k)

The rate of substrate utilization can be defined as the maximum rate of substrate utilization per unit mass of microorganisms. $K = \mu_m/Y$

The improved value of K=2.5/day appeals that the utilization rate of the substrate by the microorganism is higher with the desired concentration of the cells and increased concentration of the substrate.

Endogenous decay Coefficient (k_d)

The varying substrate concentration and the availability of energy for the cells affect the endogeneous decay coefficient. The evaluated endogeneous decay coefficient indicates the sufficient concentration of the substrate and nutrients for the microorganisms in the wastewater for their metabolic activities.

CONCLUSION

In biological treatment system, the rate at which the various components (such as organic Materials) are removed from wastewater and the rate which biomass is produced is more important.

Bio-kinetics is used to describe the growth of microorganism and removal of substrate.

The rate of bacterial growth, the maximum specific growth rate of microorganism, the yield of microorganisms and endogeneous decay coefficient is important because they directly affect the size of the reactor for a specific degree of treatment.

The design of biological treatment system based on these bio-kinetic coefficients will be accurate and reliable than the design based on the thumb rules.

The evaluated bio-kinetic coefficients are presented below.

Half – velocity constant, Ks = 867.76 mg/L
Substrate removal rate coefficient, k = 2.5, day^{-1}
Yield coefficient = 0.933mg VSS produced/mg BOD removed
Endogeneous decay coefficient, Kd = 0.015 day^{-1}
Maximum specific growth rate, = K*Y
$\mu_{Max,\ day^{-1}}$ = 2.5*0.933
= 2.3325

The bio – kinetic coefficients that were evaluated from the present study can be used in the design of activated sludge process, which will be more scientific and reliable. The existing activated sludge plant performance and any alterations required to it can also be done using the experimental results.

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News -

Global partnership award is launched

A women's network in India is collaborating with British engineers and a French water compnay to improve water delivery to impoverished urban areas. In Ecudor, a consortium of European companies is working with the government and coffee farmers to ensure that the pesticides don't contaminate water supplies. In South Africa, a small business owner is working with wome's cooperatives and the government to test-market solar technology in rural areas.

Such innovative partnerships are the focus of a global award programme launched by UNEP and other groups in January at the World Social Forum in Mumbai, India and the World Economic forum in Davos, Switzerland. The SEED Awards for "Supporting Entrepreneurs in Environment and Development" will reward people and organizations that work in partnership to devise innovative strategies for the sustainable use of natural resources.

The awards will be given for partneship proposals that show great promise and could serve as modesl. The partners - community groups, businesses, worker organizations, local authoritiies and the like- will receieve support in developing business plans, sekking funding and setting up partnerships.

"Partnerships between NGOs, governments and companies are generating new ideas on how to balance economic, social and environmental needs in a sustainable way', says Miguel Araujo of IUCN- the World Conservation Union, another of the sponsoring organizations. "However, not many people know about their success, why they are important, or how partnerships may be useful in their own communities."

The SEED Awards will be presented every two years. Other groups involved in the inititave are the Stakeholder Forum for Our Common Future, the United Nations Development Programme, Partnerships Cenral, the Global Public Policy Institute, the German government and the United Nations Global Compact office.

(UNEP & E Jan 2004)