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Kinetic Modelling for Rotating Biological Contactor for Treatment of Greywastewater

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ABSTRACT
The laboratory model of two-stage Rotating Biological Contactor (RBC) which was used in the present study is a modified one, with a provision to vary the speed of rotating blades. Grey wastewater was used to study the performance of the modified rotating biological contactor. The reactor had four rotating blades in each stage, having the size of 300 mm x100 mm x 10 mm, attached perpendicular to the shaft. The experiment was conducted for different influent COD loads and different speeds of rotating blades. Mathematical Models, Stover-Kincannon models and Grau-second-order models used for evaluating the kinetic coefficients to describe the process kinetics of RBC for treating grey water.
KEYWORDS: RBC; rotating blades; Grey water; COD; OLR.

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I. INTRODUCTION

Water usage in an Indian residential building is 4% for drinking, 4% for cooking, 41% for bathing, 22% for toilet flushing, and 15% for laundry; 14% for cleaning, sprinkling and other miscellaneous purpose. Wastewater segregation and treatment for reuse has become the best wastewater management option. Increasing the grey water reuse by lowering fresh water use for irrigation is an important step towards better environment and resource management.

Grey water is a part of used household water which has not come into contact with toilet waste. Grey water produced can vary across each household according to the number of household occupants, ages, lifestyles, and health and water use patterns. It contains waste that a household would normally wash down in drains. This content can vary between households, across different days and is dependent on daily household activities. Generally grey water contains soap, shampoo, toothpastes, cooking oils, laundry detergents, hair, and cleaning products. Characteristics of grey wastewater (1).

A physical model of rotating biological contactor (RBC) was used to study its performance for achieving desirable characteristics for reuse the treated grey water, in agriculture and landscape developments.

II. EXPERIMENTAL SET-UP

The experimental model has been designed, on the basis of empirical, as a laboratory scale RBC for an effective volume of 30 liters (In three compartments: two stages of rotating contactors and a settling tank in the third compartment). A specialty Nylon wire mesh spread on both side of all the blades to impart enhanced biofilm area. The blade rotations are arranged in the opposite direction to the liquor flow, tangentially. The shafts of each stage are connected suitably to a gear motor assembly. The speed of rotating blades is 3, 4.5 and 6rpm. The schematic diagram of experimental set-up of the modified Rotating biological contactor is presented in **Figure.1**. The grey water analysis is presented in **Table.1.**

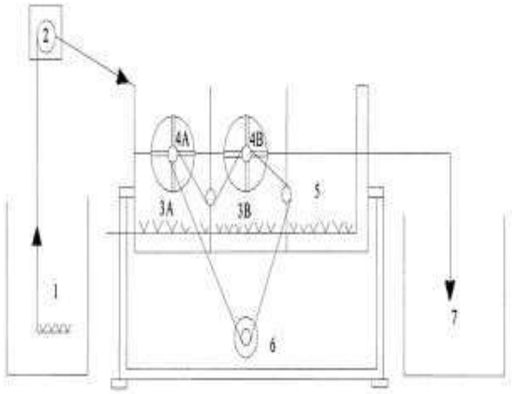


Figure-1. Schematic Diagram of Experimental Setup (RBC-105 L Capacity)

1. Grey water Mixing - Supply Tank
2. Peristaltic Pump; Miclins / 15pp
3A,3B - Stages of RBC
4A,4B - Rotating Contactors
5.Clarifier
6.Geared Motor- pulley assembly;1HP
7.Treated Grey water

Table: 1 Grey water analysis

Parameter	Unit	Domestic grey waste water
pH	-	6.5-8.5
Suspended solids	mg/l	90-400
BOD_5	mg/l	150-400
COD	mg/l	260-900
TDS	mg/l	200-1000
Oil & Grease	mg/l	10-20
Total phosphorus	mg/l	5-30
Total Nitrogen	mg/l	40-50

III. METHODOLOGY

In the present study, a two-stage RBC followed by a settling tank was envisaged as the modified RBC. Real time grey water samples were daily collected from a residential building complex, for conducting the experiment. The raw grey water was pumped at a pre-determined rate to the model by a peristaltic pump. The model was run for five different average influent substrate concentrations measured as COD (248,294,347,395 and 448 mg/l). Each stream was fed into the model for five different hydraulic flow rates (13.2, 10.5, 7.01, 5.3 and 4.4 l/h). Each combination of these two was conducted on three different speeds of the rotating blades (3, 4.5 and 6 rpm). In total, the experiment was conducted for 75 combinations of these three operating variables. All analyses were performed according to the Standard Methods (APHA, AWWA, WEF 1998) (5).An increase in the rotational speed shows decreased in removal percentage of COD.

IV. MATHEMATICAL MODELING

Mathematical modelling is an important preliminary step for implementing the wastewater treatment processes guiding systems.

a) Stover – Kincannon Model

Since the early 1970s, Stover and Kincannon have proposed a design concept of organic loading rate and established a kinetic model for bio film reactors. Stover-Kincannon model is one of the most widely used mathematical models for determining the kinetic constants. The reactor effective volume is used for the Stover – Kincannon model. This model is defined as:

$$\frac{dS}{dt} = \frac{\mu_v \ (Q \times S_0 \ / V)}{K_s \ + (Q \times S_0 \ / V)}$$

Here the substrate consumption rate dS/dt is expressed as:

$$\frac{dS}{dt} = \frac{Q}{V} \times (S_0 - S)$$

Equation is obtained from the arrangement linearizing of above equation.

$$\frac{V}{Q \times (S_0 - S)} = \frac{K_s \ V}{\mu_v \ Q \times S_0} + \frac{1}{\mu_v}$$

Where,

K_s = Saturation Constant (mg/COD/l)

μ_v = Specific Growth Rate Constant (mg.COD/l/day)

Q = Flow Rate (l/day)

S_0, S = Inflow and Outflow COD Substrate Concentration, (mg/l)

V = Reactor Volume (l)

Figure.2. indicate the graph plotted between reciprocal of the COD loading removal ($V/Q(S_0-S)$), against the reciprocal of organic loading rate, $V/(QxS_0)$ and estimated the values of Ks and μ_v. Experimental data obtained from RBC shows correlation (R^2 = 0.9889) when applied to this model. Saturation constant and specific growth rate constant were calculated 33 mg.COD/l and 44 mg.COD/l/day.

b) Grau-Second-Order Model

The general equation form the Grau kinetic model is shown in equation

$$\frac{dS}{dt} = K_s \times X \times (\frac{S}{S_0})^2$$

If equation is integrated and then linearized, equation will be obtained

$$\frac{S_0 - \theta_H}{S_0 - S} = \theta_H - \frac{S_0}{K_s \times X}$$

Knowing that organic matter removal efficiency is equal to (S_0- S) / S_0 and is expressed as E, equation can be re-written as shown in equation:

$$\frac{\theta_H}{E} = m + n \times \theta_H$$

Where,

K_s = Saturation Constant (mg/COD/l)

μ_v = Specific Growth Rate Constant (mg.COD/l/day)

Q = Flow Rate (l/day)

S_0, S = Inflow and Outflow COD Substrate Concentration, (mg/l)

V = Reactor Volume (l)

0_H = Hydraulic Retention Time (day)

E = % of COD removal

Figure.3. It shows a graph of the product of the HRT per the organic matter removal efficiency reciprocal ((S_0 × HRT)/(S_0 – S)) versus HRT, according to Grau model linerized equation. The μ_v and K_s values were calculated from the intercept and slope of the best fit line. The μ_v and K_s values are drawn on the basis of COD, as the treatment process in the study model is studied on the basis of COD removal.

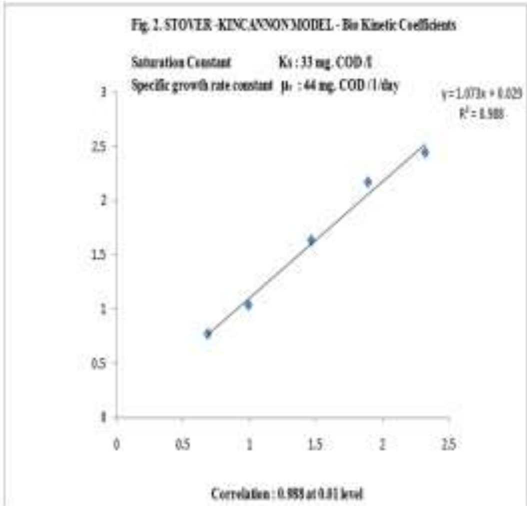
The values of μ_v and K_s for treating grey water effluent are 45, day and 53 mg COD /lit respectively. The correlation coefficient of 0.9931 is indicating that Grau model is representing the kinetics of the substrate utilization of the modified RBC for treating grey water effluent.

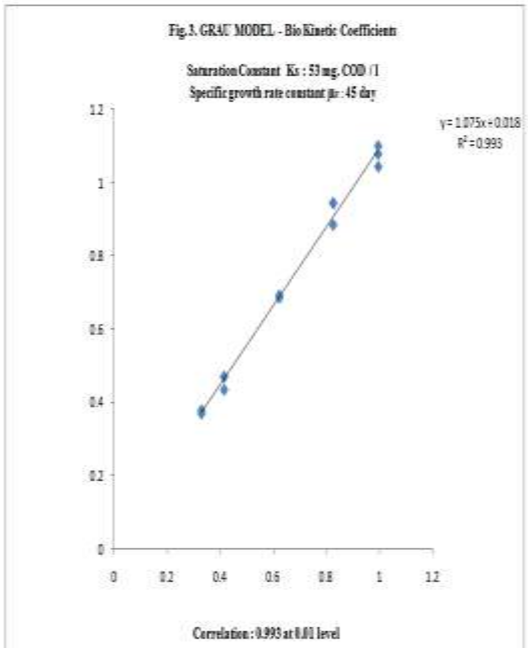
V. RESULTS AND DISCUSSION

After the RBC reactor was stabilized, synthetic wastewater was prepared and used for experimental study. An experiment was conducted for evaluating the RBC system in terms of COD removal. Reactor ran on a continuous basis for 45 days. Influent COD prepared were 248, 294, 347,395 and 448 mg/l. Initially, COD removal efficiency was poor, after some period of reactor reached to steady state condition and removal efficiency was improved to 82.68%. The COD removal efficiency for varying OLR from 0.054 to 0.163 kg COD/m^2/day. The maximum COD removal was observed for 95.07% against OLR of 0.234 kg.COD/m2.day, for the rotational speed of 3 rpm.

VI. CONCLUSION

The optimum rotational speed of the blades is understood to be the lowest possible. Though, 3 rpm of the blade rotational speed was found to be optimum from the results of the experiment, it could be still lower in the full fledged, field level RBC plants, for better removal of COD from the waste streams. The correlation coefficient r^2 was chosen as the criterion for choosing the most suitable model to represent organic matter removal kinetics. Considering this criterion, the Stover-Kincannon was more suitable than the Grau-second-order model.





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