# MATHEMATICAL 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, Kornegay model and Modified Stover-Kincannon model 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.

## 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.

**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 litres (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 bio film 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.**

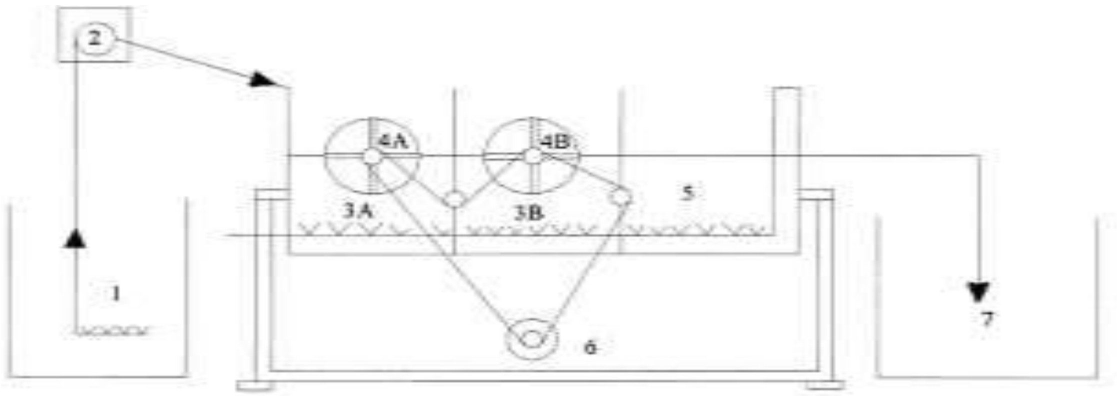


Figure-1. Schematic Diagram of Experimental Setup (RBC-105 L Capacity)

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 |

## 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) (4).An increase in the rotational speed shows decreased in removal percentage of COD.

## MATHEMATICAL MODELING

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

## KORNEGAY MODEL

The first model ever formulated on full-fledged RBC was made by Kornegay and Andrews (1975).

The Kornegay kinetic model is essential a steady-state model, assuming complete mixing in the reactor.

$$\frac{Q}{S_o - S_e} = \frac{PAS_e}{(K_s + S_e)} + \frac{((\mu_{max})_s / Y_s) X_s V S_e}{(K_s + S_e)}$$

(Attached growth) (Suspended growth)

Where

| | | |
|---|---|---|
| $Q$ | = | Hydraulic flow rate, 1/day |
| $S_o$ | = | Influent substrate concentration, mg.COD/l |
| $S_e$ | = | Effluent substrate concentration, mg.COD/l |
| $P$ | = | Area capacity constant, g.COD/$m^2$/day |
| $A$ | = | Total surface area of rotating discs, $m^2$ |
| $K_s$ | = | Saturation constant, mg.COD/l |
| $\mu_{max}$ | = | Maximum specific growth rate, day |
| $X_s$ | = | Active biomass per unit volume of attached growth, mg/l |
| $Y_s$ | = | Yield coefficient for suspended growth |

In this equation, the first component on the LHS is contributed by treatment due to attached growth of microorganisms in the discs. The second component on the RHS is contributed by treatment due to suspended growth of microorganisms in the mixed liquor of reactor. The model is deduced to the following state, for solving it mathematically for establishing P area capacity constant and $K_s$, saturation constant of the modified RBC of the present study. The above equation may then be written as:

$$S_e \left[ 1 - \frac{(\mu_{max} / Y_s) X_s V_s}{Q(S_0 - S_e)} \right] = P \frac{AS_e}{Q(S_o - S_e)} - K_s$$

So, the area capacity constant P as slope of the line and saturation constant $K_s$ as Y intercept, can be calculated by plotting graph for

$$S_e \left[ 1 - \frac{(\mu_{max} / Y_s) X_s V_s}{Q(S_0 - S_e)} \right] \text{ versus } S_e \frac{AS_e}{Q(S_o - S_e)}$$

in Y and X axis respectively.

The plot between X and Y is drawn as best fit line using statistical tools and the estimation of bio kinetic constants P and $K_s$ is shown in **Fig 2.**

The experimental results of modified RBC plant of the present study in treating grey water are used to evaluate the bio kinetic constants like P and $K_{s.}$ As the experiments were conducted on the basis of COD, bio kinetic constants, P and $K_{s,}$ are evaluated, only on the basis of COD of the grey water samples, independently.

Statistical package, namely SPSS, was used for drawing the best fit line and calculating correlation coefficients shown in **Fig. 2.**

## MODIFIED STOVER-KINCANNON MODEL

It is one of the most widely used mathematical models for determining the kinetic constants.The effective volume of reactor is used for the Modified Stover- Kincannon model. This model is expressed as:

$$\frac{dS}{dt} = \frac{\mathrm{Umax} \times (Q \times \frac{\mathrm{So}}{\mathrm{V}})}{\mathrm{kB} + (Q \times \frac{\mathrm{So}}{\mathrm{V}})}$$

here the substrate consumption rate *dS/dt* is expressed as:

$$\frac{dS}{dt} = \frac{Q}{V} \times (\mathrm{S_o}\text{-}\mathrm{S})$$

Equation (5) is obtained from the arrangement and linearizing of Equation (3)

$$\frac{V}{Q \times (\mathrm{So} - \mathrm{S})} = \frac{\mathrm{kB}}{\mathrm{Umax}} \frac{V}{Q \times \mathrm{So}} + \frac{1}{\mathrm{Umax}}$$

The value of the Stover- Kincannon kinetic constants can be obtained by plotting V /Q (So -S) versus V /Q So, according to Equation. The value of $K_s$ and $U_{max}$ is obtained from the slope of the straight line.

Statistical package, namely SPSS, was used for drawing the best fit line and calculating correlation coefficients shown in **Fig. 3.**

## 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.

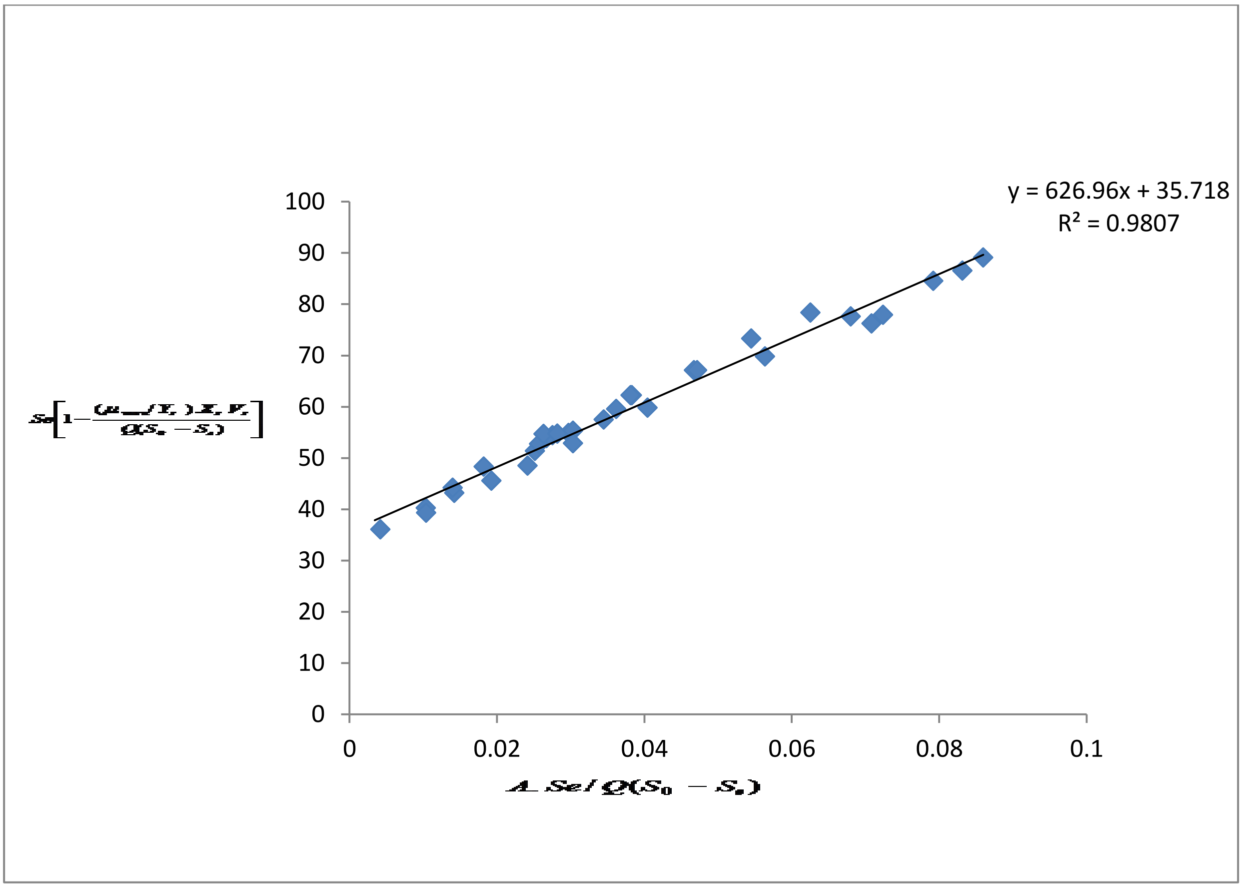


**Fig.2 Kornegay Model Graph**

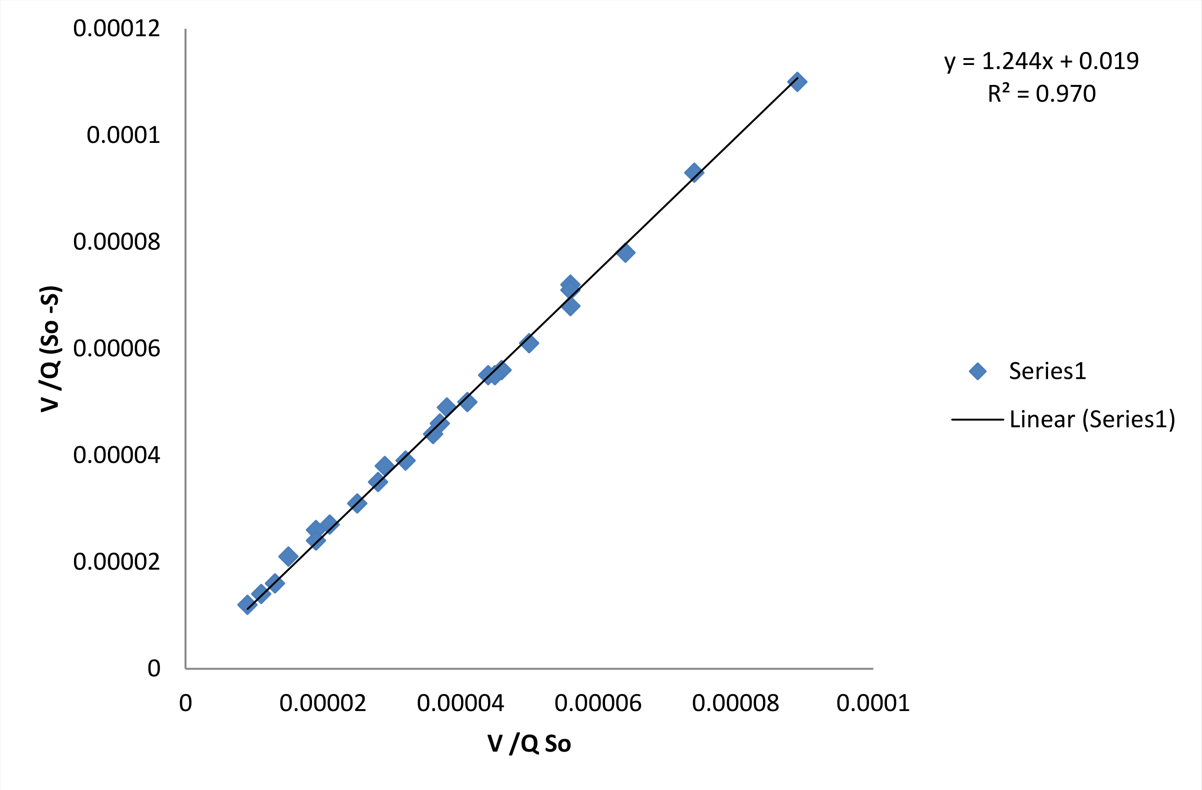


**Fig .3 Modified Stover-Kincannon Model Graph**

## 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 Kornegay was more suitable than the Modified Stover-Kincannon model.

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