# Biodegradation Kinetics on The Treatability of 2,4-DCP in An UASB Reactor with Co-Substrate

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***Abstract-*** ***Bio mineralization of 2,4 -DCP and kinetic constant for the treatability of the 2,4-DCP has been obtained. Models such as Monod's, Haldane's, Contois model, Stover-Kincannon model and Grau-second order multi-component substrate removal model was used to find the kinetic constant. Saturation value constant ($K_B$) and maximum utilization rate ($R_{max}$) were calculated as 7.863 g/L d and 5 g COD/L d representing the substrate removed rate of the microorganism by modified Stover–Kincannon model. Kinetic coefficients $K_s$=3.26 mg/L and $K_i$=175.17 mg/L with high correlation coefficient ($R^2$) of 0.998 was obtained by Haldane model. Larger values of $K_i$, indicate less inhibition effect of 2,4-DCP on the growth of microorganisms.***

***Indexed Terms-*** ***Biodegradation, 2,4 –DCP, UASB reactor, Bio kinetics, Haldane model.***

## I. INTRODUCTION

Biological mineralization of chlorinated aromatic complexes has been studied by many investigators (Kim et al., 2002; Wang et al., 2000). Various microorganism have been engaged in degrading phenol and chlorophenols (Kim and Hao, 1999; Wang et al., 2000). Higher concentrations of chlorophenols are more repressive to microorganisms but however, acclimatization of microorganisms to chlorophenols were found to enhance the biodegradative ability of the organisms and improve restraining effects to some span (Annachhatre and Gheewala, 1996). Elevated concentrations of DCP were found to upsurge the interval of the lag phase and decrease the degree of degradation. Addition of co-substrate to the medium has improved the level of degradation of chlorinated aromatic compounds (Wang and Loh, 1999; Tay et al., 2001) and anaerobic organisms were reported to be more efficient in the degradation of chlorophenols than aerobic organisms (Atuanya et al., 2000; Sivarajan et al., 2019).

To govern the association amid the design data and experimental results, to predict the performance and design criteria and for optimizing the process, kinetic models are generally used. Various models involving few variables are easier to monitor and are needed for industrial applications in order to determine the kinetic constants (Iza *et al*., 1990). The aim of this study was to investigate the capability of the microorganism to degrade 2,4-DCP with starch as co-substrate in an UASB reactor and to determine the kinetic and inhibition constants using the investigational data.

## II. MATERIALS AND METHODS

### *A. Experimental system*:

Anaerobic treatability of synthetic 2,4-DCP was studied using a UASB reactor and its operational performance was investigated. The process essentially contained a raw feed storage tank, feed pump, acidogenic reactor, methanogenic reactor, and gas measurement assembly. The volume of acidogenic and methanogenic reactors were devised in 1:4 ratio. The reactor was fed with synthetic starch water with an OLR of 2.2 kg COD/$m^3$d, 24 h HRT, pH of 7.2 along with nutrients at a ratio of 100:5:1(McDougall, 1994). During the start-up period the reactor was operated at an up-flow velocity of 0.08 m/h (Metcalf& Eddy,2003). After stabilization of the reactor, it was operated with synthetic starch and 2,4-DCP at an optimized mixing ratio of 80:20 for various concentrations at constant HRT.

### *B. Analytical methods*:

Samples were withdrawn aseptically through the ports each day and the supernatants were analysed for 2,4-DCP content. For determination of phenol and its derivatives in the form of the phenol index the standard 4-aminoantipyrene colorimetric method was used for DCP analysis as specified (Greenberg et al., 1989). Biomass concentrations were determined by initially filtering the samples through a Millipore filter

(pore size 0:45 mm), and then dried to a constant weight at 105 $^0$C. COD was resolute by the closed reflux method as per APHA, 2005.

## III. RESULTS AND DISCUSSION

The kinetic studies for the results obtained on continuous degradation of 2,4-DCP with starch water as co-substrate at various concentrations were carried out. To ascertain the kinetic parameters required, four steady state data sets were used. A graph was plotted using Eq. $\frac{(S_0 - S)}{\theta_H \times X} = \frac{1}{Y} \times \left(\frac{1}{\theta_C}\right) + \frac{1}{Y} \times K_d$ to determine the values of yield coefficient $Y$ and decay coefficient $k_d$ (Figure 1) and the value of maximum specific growth rate $\mu_{max}$ and half saturation constant $K_S$ for a UASB reactor is determined from figure 2 plotted using equation $\frac{\theta_C}{1+\theta_C \times K_d} = \frac{K_S}{\mu_{max}} \times \frac{1}{S} \times \frac{1}{\mu_{max}}$. On account of poor correlation ($R^2$<0.3) the Monod model was not appropriate for interpreting the kinetic data of the UASB reactor treating 2,4-DCP with starch as co-substrate.

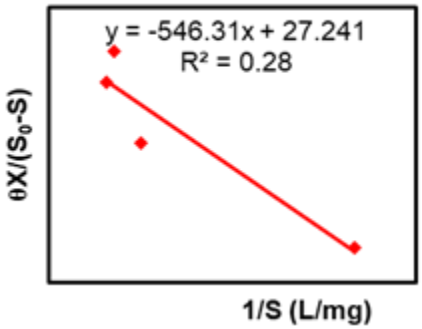


Fig 1 (Y) and ($k_d$) from Monod model

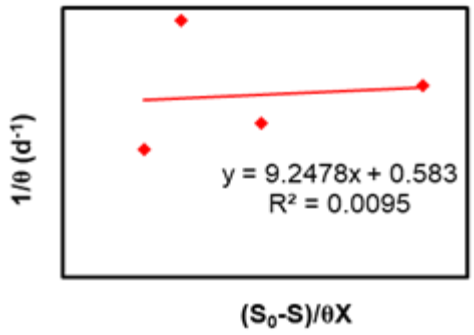


Fig 2 ($\mu_{max}$) and ($K_S$) for Monod model

The values of maximum specific growth rate ($\mu_{max}$) and kinetic constant β for the Contois model were determined from the figure 3 by plotting the Eq. $\frac{\theta_C}{1+\theta_C \times K_d} = \frac{\beta}{\mu_{max}} \times \frac{X}{S} + \frac{1}{\mu_{max}}$. Since the regression coefficient for Contois model was less than 0.3 it was also not suitable for interpreting with the data of the UASB reactor.

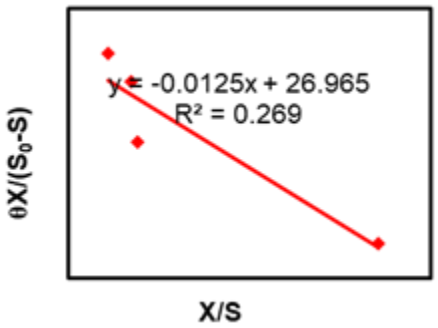


Fig 3 ($\mu_{max}$) and (β) for Contois model

The kinetic coefficients of Haldane model, Eq. $\frac{\theta_H \times S \times X}{(S_0 - S)} = \frac{S^2}{K_i \times k} + \frac{S}{k} + \frac{K_s}{k}$ were plotted in figure 4, between effluent substrate [S] versus Substrate utilization rate [S/U] where, U=[($S_o$-S)/θX]. For UASB reactor the values of kinetic coefficients $K_s$=3.26 mg/L and $K_i$=175.17 mg/L with high correlation coefficient ($R^2$) of 0.998 was obtained. Larger values of $K_i$, indicate less inhibition effect of 2,4-DCP on the growth of microorganisms.

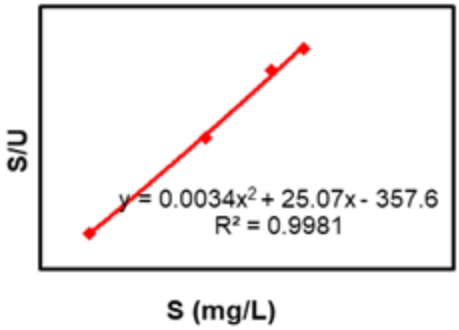


Fig 4 $K_s$ and $K_i$ for Haldane model

The modified Stover–Kincannon model was applied to determine kinetic constants for UASB reactor treating synthetic 2,4-DCP and starch water. Figure 5 indicate the graph plotted between reciprocal of the COD loading removal [$V/(Q(S_0-S)$], against the reciprocal of total organic loading rate, $V/(Q\times S_0)$, and estimated the values of $1/R_{max}$ and $K_B/R_{max}$. The data obtained shows high correlation ($R^2$=0.855) when applied to this model. Saturation value constant $K_B$ and maximum utilization rate $R_{max}$ were calculated as 7.863 g/L d and 5 g COD/L d representing the substrate removed rate of the microorganism. From the values of $R_{max}$ and $K_B$, the effluent COD of the UASB reactor can be predicted from the equation

$$S = S_0 - \frac{R_{max} S_0}{K_B + (QS_0 / V)}.$$

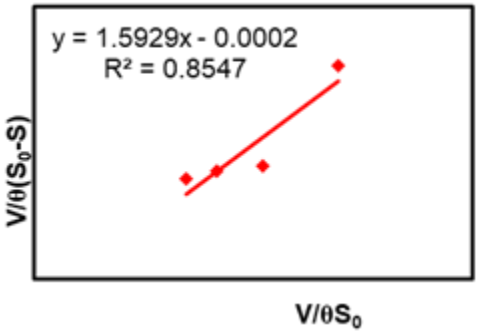


Fig 5 Stover-Kincannon model plot for UASB reactor

Grau-second order multi-component substrate removal model was developed by plotting between HRT versus HRT/E (Efficiency) (Figure 6).The values of a and b were calculated from the intercept and slope of the straight line from the figure, the values of a and b were found to be 0.0985 and 1.396 with high correlation coefficients of 0.8543. The multi-component substrate removal rate constant ($k_s$) for UASB reactor was calculated from the equation $a=S_0/(k_sX)$ as 0.55 per day. In order to predict effluent substrate concentration by using influent substrate concentration and hydraulic retention time, the values of a and b are substituted and rearranged in Eq.

$$V = \frac{QS_0}{(R_{max} S_0 / S_0 - S) - K_B}$$

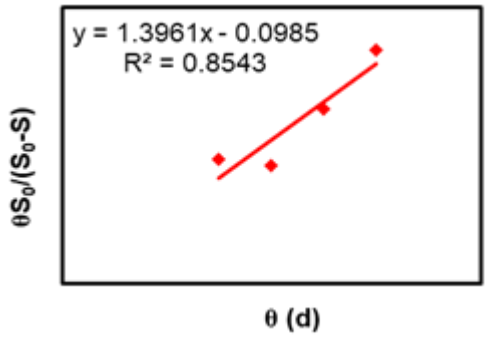


Fig. 6 Kinetic constants (*a*, *b* and $k_s$) for Grau-second order multi-component substrate removal model

The kinetic data discloses that Stover-Kincannon, Grau second order multi-component substrate removal kinetics and Haldane model were more appropriate than the other models for predicting the performance of the bench scale biphasic UASB reactor when the regression coefficients and kinetic coefficients were compared. Table 1 summarizes the constants determined from the various models.

Table 1 The values of constants determined from the various models.

| Kinetic Model | Kinetic Parameter | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $K_s$ (mg/L) | $K_i$ (mg/L) | a (per day) | b (dimensionless) | $k_s$ (per day) | $K_B$ (g (L per day)) | $R_{max}$ (g COD (L per day)) | ($R^2$) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Haldane | 3.26 | 175.17 | - | - | - | - | - | 0.998 |
| Grau second order | - | - | 0.0985 | 1.396 | 0.55 | - | - | 0.854 |
| Modified Stover-Kincannon | - | - | - | - | - | 7.863 | 5 | 0.855 |

The kinetic model are useful contrivance in designing and optimization the process by reducing extensive and complex experimental data to simple and convenient mathematical expression.

## CONCLUSION

Based on the study the following points have been concluded**,** Kinetic models such as Monod's, Haldane's, Contois model, Stover-Kincannon model and Grau-second order multi-component substrate removal model were used to obtain kinetic constant. During the start-up period the reactor was operated with up flow velocity of 0.08 m/h. The kinetic data revealed that Stover-Kincannon, Grau second order multi-component substrate removal kinetics and Haldane model were more appropriate than the other models. Saturation value constant $K_B$ and maximum utilization rate $R_{max}$ were estimated as 7.863 g/L d and 5 g COD/L d representing the substrate removed rate of the microorganism by modified Stover–Kincannon model. Kinetic coefficients $K_s$=3.26 mg/L and $K_i$=175.17 mg/L with high correlation coefficient ($R^2$) of 0.998 was obtained by Hald**a**ne model. Larger values of $K_i$, indicate less inhibition effect of 2,4-DCP on the growth of microorganisms.

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