Modeling of kinetics approach on the removal in methyl ethyl ketone using pressmud based biofilter systems

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Abstract The removal of toxic methyl ethyl ketone (MEK) is studied in a lab scale biofilter packed with pressmud as packing materials. The biofiltration operation is divided into 4 phases for a period of 200 days. The maximum removal efficiency of 98 % is achieved during phase I for an inlet concentration of 0.2 g m^{-3} at a gas flow rate of 0.03 m^{-3} of MEK. The model simulation results have been reproduced and compared with the above sets of experimental data. Three different model variations are considered: model with low inlet MEK concentration, with high inlet MEK concentration, and with air flow rate modification. A sensitivity analysis has been performed on model to study the effect of important parameters on the removal efficiency. Model limitations and improvements have been highlighted.

Keywords MEK · Pressmud · Sensitivity · Decay ratio

Introduction

Over the past decade, air pollution caused by rapid development of industries has become a social alarm. Volatile organic compounds (VOCs), which contain odorous sulfured hydrocarbons, chlorinated hydrocarbons and aromatic compounds, must be efficiently control before their emissions into the environment (Wang et al. 2009; Rene et al. 2010).

Methyl ethyl ketone (MEK) was widely used industrial chemicals. This MEK compound was designed high-priority toxic chemicals. Large volumes of these ketone compounds are released into the atmosphere during manufacturing processes every year, leading to the endangerment of air quality and public health. Some reports concerned the biofiltration of ketone compounds. MEK biodegradation by *Pseudomonas* sp. KT-3 was studied by Lee et al. (2006). MEK degradation by using biofilters with a pure strain of *Rhodococcus* sp. or a mixed culture of microbes showed no advantage of a pure culture; and the mass-transfer mechanism is macropore controlled in both the granular activated carbon and compost media (Deshusses and Hamer 1993).

The maximum elimination capacity achieved were $50 \text{ gm}^{-3} \text{ h}^{-1}$ for MEK at the inlet concentration of 300 mg m^{-3} (Cai et al. 2004). The maximum elimination capacity of MEK was 5.82 kg COD/m^3 3 days. Using backwashing and starvation/stagnant strategies, long-term stable removal efficiency over 99 % was retained for loading rate up to $3.52\text{--}5.63 \text{ kg COD/m}^3$ 3 days (Cai et al. 2006a, b). The biofilter provided high removal efficiency within the critical loading of each VOCs. The biofilter easily acclimated to the oxygenated compounds (MEK) The destructed aromatic compounds were eliminated exclusively by aerobic biodegradation; however, the destructed oxygen compounds were eliminated by aerobic biodegradation and possible denitrification Cai et al. 2006b). Recently, we had indicated that the process for degradation of VOCs in a composite bead biofilter could be divided into lag, log growth and maximum stationary three phases, and the log growth and maximum stationary phases were important for controlling the removal efficiency of biofilter (Chan and Chang 2006a, b).

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Recently, biological technology has frequently been applied to control waste gas emissions since it offers numerous economical and environmental advantages to some conventional physicochemical technologies (such as absorption, adsorption, catalytic oxidation, scrubbing and thermal). Among all the biological technologies, biofiltration is regarded as a mature technique to purify waste gases polluted with large volumes and low concentrations of VOCs (Sakuma et al. 2008; Bordel et al. 2008; Park et al. 2009; Popat and Deshusses 2010). Efficient removal of, for example, aromatics, chlorinated hydrocarbons, organic sulfur compounds, and other VOCs had been reported in many lab-scale biofilters (Sempere et al. 2008; Giri et al. 2010; Chen et al. 2010; Rene et al. 2010).

However, recent studies have revealed that additional surfactants and conventional carbon sources could enhance the biofiltration of hydrophobic and xenobiotic compounds (Tian et al. 2003; Langolf and Kleinheinz 2006; Cho et al. 2007; Rene et al. 2009). Miller and Allen (2005) developed a modified model to describe the mass transfer and removal characteristics of hydrophobic compounds in the biofilters.

In this study, a lab-scale aerobic biofilter (BF) inoculated with an acclimated microbial consortium was set up to evaluate its treatment for MEK. During the continuous operation of more than 4 months, the removal efficiency (RE) and the elimination capacity (EC) were investigated at different process meters. Finally, the results was investigate the validity of the model of Li and De Visscher, De Visscher and Van Cleemput and modified the model equation to include substrate inhibition using Haldane kinetics and influence of gas flow rate on MEK degrading activity.

Materials and methods

Biofilter set-up

The biofilter (Fig. 1) was made from a acrylic cylindrical tube having 50 mm in diameter and 1000 mm in height. It was divided into three sections, middle section being filled with pressmud and berl saddles as the packing materials (770 mm/layer). Along the column, there were three sampling ports for gas-concentration measurement, located at 25, 50 and 75 cm (outlet port), respectively. Additional ports located at 12.5, 32.5, and 62.5 cm were used for filter material sampling and temperature or pressure-drop measurement.

MEK contaminated stream was produced by passing air through a sparger containing MEK (purity 97 %, SD fine Chemical Company, India) and then mixed with the other flow of the ambient air (purified by activated carbon to remove other background VOCs). Different ratios of these

streams, which were controlled by the rotameters and the humidifier, determined the inlet concentration MEK and the relative humidity of the mix stream. A micronutrient solution [mg/L, NH_4Cl 860, NaNO_3 2250, K_2HPO_4 600, KH_2PO_4 150, MgCl_2 60, CaCl_2 6 and Fe_2SO_4 3 (pH 7.2)] was fed to the BF through a peristaltic pump (180 mL/min spraying for 5 min every day), supplying the nutrient and removing the less-active biofilm or the accumulated metabolites. Recycled liquid 500 mL was replaced by the fresh solution every 3 days (average liquid residence time of 9 days).

Startup and operation of the biofilter

Cox and Deshusses (2001) indicated that the specific microorganisms could accelerate the biofilm formation within a short time, especially for the removal of poorly biodegradable compounds. In this study, the pure MEK degraders isolated from the active sludge (a full-scale wastewater treatment plant, Shasun Industries, Pondicherry, India), which was acclimated by MEK as the sole carbon and energy source for nearly 2 months. Before the start-up of biofilter, the active sludge from the same place was acclimated by MEK for nearly 1 week to develop a stable microbial consortium, and then mixed with the prepared pure cultural suspensions (volume ratio 6:1). The obtained inoculation was re-circulated through the packed filter using a peristaltic pump at a rate of 0.1 L/min for 24 h to allow the biomass to attach to the packing materials.

After inoculation, the biofilters were operated continuously under the same conditions nearly 4 months, and the difference between them was that the circulated liquid used in the control one was sterilized under 110 °C, 40 min. During the start-up phase, the empty bed retention time (EBRT) and the pH of the circulated liquid were controlled at 58 s and 6–7, respectively. Gaseous influent/effluent concentration of MEK and CO_2 were analyzed daily, and the microbial analysis was conducted every 10 days. The performance of biofilters is expressed in terms of EC and RE. The performance parameters are defined below 1.

Modelling

In this section the biofilter model of Li and De Visscher is presented so that the readers can follow the analysis and discussion presented in the subsequent sections. In the toluene biofilter model by Li and De Visscher, the biofilter is considered as a plug flow reactor. The height of the biofilter is divided into a number of subsections and the mass balance in each of these subsections is given as follows:

Fig. 1 Schematic view biofiltration setup

$$QC_j = QC_{j+1} + r_j A \Delta z \quad (1)$$

where Q is the air flow rate (m^3/h), A is cross-sectional area of the biofilter (m^2), C_j and C_{j+1} are concentrations (g/m^3) of the gas-phase pollutant (toluene) in the subsections j and $j + 1$ respectively, Δz is the subsection height (m), and r_j is the volumetric biodegradation rate (g/m^3 biofilter/h) in the subsection j of the biofilter.

Equation (1) can be written in the following differential form with the biofilter height z as the independent variable:

$$\frac{dC}{dz} = -\frac{A}{Q} r \quad (2)$$

The expression for the volumetric biodegradation rate r depends on whether substrate inhibition is considered or not. On the basis of Pirt kinetics and logistic growth rate expression, De Visscher and Van Cleemput developed the following expression for microbial growth for methane biofiltration:

$$\mu = \mu'_{\max} \frac{\left[1 - \frac{V_{\max}}{V_{\max, \max}}\right] S}{K_m + S} - a \quad (3)$$

where $V_{\max}$ is the maximum degradation rate ($\text{g pollutant}/\text{m}^3$ biofilter/h), $V_{\max, \max}$ is the maximum attainable value of

$V_{\max}$ (g pollutant/m³ biofilter/h), S is the substrate concentration in the liquid phase (g/m³), K_m is the Michaelis–Menten constant (g/m³), a is the decay rate of the microbes (h⁻¹), μ is the specific growth rate (h⁻¹), and $\mu_{\max}$ is the actual maximum specific growth rate (h⁻¹). The change of $V_{\max}$ with time is given by the following equation:

$$\frac{dV_{\max}}{dt} = \mu V_{\max} \quad (4)$$

De Visscher and Van Cleemput proposed that $V_{\max}$ attains a maximum value $V_{\max, \max}$ during the course of biofiltration. Most biofilter models assume a uniform biofilm structure and a constant $V_{\max}$ throughout the biofiltration process. However, in reality, the thickness of bio-layer changes with substrate concentration and thus changes with the position in the biofilter (Devinny et al. 1999). The biofilm is expected to grow the thickest where the substrate concentration is the highest. Therefore, $V_{\max}$ is not constant along the biofilter height.

Biofilter model 1 (without substrate inhibition)

If substrate inhibition is not considered, the volumetric biodegradation rate r_j is given by Michaelis–Menten kinetics:

$$r_j = V_{\max} \frac{S_j}{K_m + S_j} \quad (5)$$

where S_j is the liquid-phase concentration (g/m³) of the pollutant and is related to C_j by Henry's law as follows:

$$S_j = \frac{C_j}{H_{cc}} \quad (6)$$

where H_{cc} is the dimensionless Henry's constant for the pollutant. In each subsection, the microbial growth rate is given by De Visscher and Van Cleemput model:

$$\mu_j = \mu'_{\max} \frac{\left[1 - \frac{V_{\max, j}}{V_{\max, \max}}\right] S_j}{K_m + S_j} - a \quad (7)$$

At steady state, there is no net microbial activity ($\mu_j = 0$) and Eq. (7) can be written as follows:

$$V_{\max, j} = \left[1 - \frac{a}{\mu'_{\max}} \left(1 + \frac{K_m}{C_j/H_{cc}}\right)\right] V_{\max, \max} \quad (8)$$

Equation (8) indicates that the $V_{\max}$ is not constant but changes with the pollutant concentration at different biofilter height positions. Equation (2) combined with Eqs. (5) and (8) can be solved numerically to study the pollutant concentration along the biofilter height.

Biofilter model 2 (with substrate inhibition)

In case of substrate inhibition, Haldane kinetics gives the following expression for the microbial growth rate:

$$\mu_j = \mu'_{\max} \frac{\left[1 - \frac{V_{\max, j}}{V_{\max, \max}}\right] S_j}{K_m + S_j + \frac{S_j^2}{K_I}} - a \quad (9)$$

where K_I is the inhibition constant (g/m³). Similarly, the volumetric biodegradation rate assumes the following form

$$r_j = V_{\max, j} \frac{S_j}{K_M + S_j + \frac{S_j^2}{K_I}} \quad (10)$$

Again, under steady-state, μ_j becomes equal to zero and Eq. (9) becomes as follows:

$$V_{\max, j} = \left[1 - \frac{a}{\mu'_{\max}} \left(1 + \frac{K_m}{\frac{C_j}{H_{cc}}} + \frac{C_j}{H_{cc} K_I}\right)\right] V_{\max, \max} \quad (11)$$

In case of substrate inhibition, Eq. (2) combined with Eqs. (10) and (11) can be solved numerically to study the pollutant concentration along the biofilter height.

Biofilter model 3 (with flow rate modification)

The performance of a biofilter is significantly affected by the flow rate of air. At high air flow rates, the biofilm layer becomes thinner and more uniform (Haldane 1930), and mass transfer and biodegradation are favored (Li and De Visscher 2008). For biofilters operating under varying air flow rates with substrate inhibition (model 2), an empirical equation is used to describe the effect of air flow rate Q on the value of $V_{\max, \max}$ (Li and De Visscher 2008):

$$V'_{\max, \max} = V_{\max, \max} Q^p \quad (12)$$

where ma is the flow-rate-modified maximum value of $V_{\max, \max}$. The value of p is between 0 and 1 (Li and De Visscher 2008). To include the effect of varying air flow rate, Eq. (12) replaces $V_{\max, \max}$ in Eq. (11) of model 2. The equations can then be solved to study the concentration of pollutant along the biofilter height.

Results and discussion

Overall system performance under variable loading condition

At start-up, the inoculum solution was poured onto the package, and recycled several times in order to ensure

homogeneous distribution of the microbial population inside the filter bed. During this period, the biolayer was still in the state of formation and its thickness varied because the microbial population had to acclimatize to the filter media, which caused fluctuations in the rate of biodegradation. For this reason, although experiments of biofiltration of air polluted with VOC were performed immediately after the filter inoculation, only the steady state results, obtained after the adjustment period of 6 days, are discussed in the present work. The polluted air flow rate through the biofilter was held constant to $0.03 \text{ m}^3 \text{ h}^{-1}$ for MEK, corresponding to empty bed residence time 2.81 min.

Biofiltration of air contaminated with various inlet concentrations of MEK for pressmud

The gas flow rate and the inlet pollutant concentration are the most important parameters in the biofiltration process. Both parameters quantify the amount of pollutant to be removed in the biofilter. The performance of a biofiltration unit is strongly dependant on the pollutants inlet concentration. Biofiltration has proven to be highly efficient for dilute air streams and even for more concentrated emissions of easily biodegradable pollutants.

The biofiltration of gas stream containing MEK was carried out for 200 days at various operating conditions in an up flow mode pressmud based biofilter as shown in Table 1. The Reactor had been operated in four stages. Each stage is divided into four phases as shown in Fig. 2. Various flow rate and concentration were maintained so that the corresponding loading rate could be maintained and regulated in the reactor to study the performance of the reactor. Table 1 shows the inlet concentration, inlet gas flow rate to be supplied

The first phase of the experiment lasted for 50 days (Fig. 3). In the I phase of the first run, the flow rate and inlet concentration of MEK were maintained at $0.03 \text{ m}^3 \text{ h}^{-1}$ and at $0.2 \pm 10 \% \text{ gm}^{-3}$, respectively, so that the average loading rate of $4.08 \text{ gm}^{-3} \text{ h}^{-1}$ can be applied to the reactor as given in Fig. 4. The corresponding EBRT was maintained at 2.8 min. Gradual increase in removal efficiency was observed. It was evident from the Fig. 3 more than 97.9 % removal was obtained after 8 days of operation. These results are in consistent with the reported acclimatization periods from several weeks to several months (Saravanan and Rajamohan 2009).

In run II, average loading rate has been increased by nearly twice from 4.08 to $8.16 \text{ gm}^{-3} \text{ h}^{-1}$ as shown in Fig. 4. The flow rate and EBRT was maintained at $0.06 \text{ m}^3 \text{ h}^{-1}$ and 1.47 min, respectively. In this run, the average inlet MEK concentration was kept constant at $0.2 \pm 10 \% \text{ gm}^{-3}$. Due to the shock load there was a fall in

Table 1 Summary of experimental plan

Days of operation	Gas flow rate ($\text{m}^3 \text{ h}^{-1}$)	Inlet concentration (gm^{-3})
0–10	0.03	0.2
11–20		0.4
21–30		0.6
31–40		0.8
41–50		1.2
0–10	0.06	0.2
11–20		0.4
21–30		0.6
31–40		0.8
41–50		1.2
0–10	0.09	0.2
11–20		0.4
21–30		0.6
31–40		0.8
41–50		1.2
0–10	0.12	0.2
11–20		0.4
21–30		0.6
31–40		0.8
41–50		1.2

the removal efficiency of MEK in earlier stage from 97.9 to 85 % and took 3 days to recover. Later it recovered gradually from this shock loading to 95 %.

In run III, average loading rate was increased from 8.16 to $12.14 \text{ gm}^{-3} \text{ h}^{-1}$ and flow rate of main stream and EBRT was $0.09 \text{ m}^3 \text{ h}^{-1}$ and 0.7 min. The inlet concentration was kept constant at maintained at 0.6 gm^{-3} . The With the sudden increase in the loading rate to the reactor removal efficiency initially decreased from 95 to 70 % but later on it recovered gradually from this shock loading to 90 % at steady state. Run III lasted for 10 days.

In run IV, loading rate has been increased from 12.14 to $16.33 \text{ gm}^{-3} \text{ h}^{-1}$ and flow rate of main stream and EBRT was $0.12 \text{ m}^3 \text{ h}^{-1}$ and 0.45 min. The concentration was kept constant at 0.2 gm^{-3} . Due to this shock load there was a fall in the removal efficiency from 90 to 61 % and it took 3 days to recover. It recovered gradually from this shock loading to 88 % at steady state.

The analysis of the biofilter performance shows that both EC at constant IL and X for constant MEK inlet concentration decrease when the gas flow rate is increased. Higher gas flow rate decreases the contact time between the pollutant and the microbial population and consequently lowers the filter bed efficiency and EC. The general trend of the variation of EC versus the MEK IL for the various gas flow rates shows an increase in EC with increasing MEK IL to a certain value which depends on the gas flow

Fig. 2 Start-up of the biofilter for the removal of MEK using pressmud based biofilter

Fig. 3 Performance of biofilter for the removal of MEK using pressmud based biofilter

Fig. 4 Inlet load Vs elimination capacity for the removal of MEK using pressmud based biofilter

Table 2 Model 1 parameters (with low concentrations)

Parameter	Value	Unit
$\mu_{\max}$	0.28	h^{-1}
K	3.495	g m^{-3}
A	0.0017	h^{-1}
$V_{\max}$	50	$\text{g pollutant m}^{-3} \text{ of biofilter h}^{-1}$
H_{CC}	0.313

Fig. 5 Model 1 (low MEK concentration) prediction of MEK gas-phase concentrations along the biofilter height. MEK-contaminated air flow rate is $0.03 \text{ m}^3 \text{ h}^{-1}$, inlet MEK gas-phase concentration is 0.2 gm^{-1}

rate. In these situations, the increase of the MEK inlet concentration enhanced the transfer rate of MEK from the gas phase to the biofilm so that more microorganisms participate to the biodegradation activity. This behavior can be described as a diffusion limitation regime.

At the maximum EC, the entire active microbial population is involved in the biodegradation kinetics and the diffusion limitation does not occur for these operating conditions. As IL is increased above the upper limit of the diffusion limitation regime, EC first remains constant to its maximum value and then decreases for higher IL. Increase in the MEK inlet concentration above the maximum EC conditions causes a significant decrease in both X and EC. Such a behavior was not expected since previous research works (Saravanan and Rajamohan 2009; Saravanan et al. 2010, 2015) reported a constant EC with increasing pollutant IL in the absence of diffusion limitation, i.e., in the reaction limitation

Application of models

Biofilter model 1

The non-linear coupled differential equations made up of Eqs. (2), (5) and (8), are solved using the ODE command in MATLAB to describe the variation of gas-phase MEK concentration along the biofilter height for the low MEK concentration. The biofilter had an inner diameter of 10 cm, a total height of 75 cm and an effective volume of 4 L (empty basis) and consisted of three stages. A mixture of pressmud and berl saddles was supplied acted as packing material. The kinetics parameters were find out and are summarized in Table 2. Using these parameters the gas-phase MEK concentration along the biofilter height was predicted. Figure 5 shows a good agreement between the model simulation results and the experimental results and model. Model 1 developed by Li and De Visscher showed excellent agreement with these experimental data and are given in Fig. 6.

Biofilter model 2

When the substrate loading is very high the model 2 was suggested. In this case, the Eq. (2) combined with Eqs. (10) and (11) can be solved to study the variation of gas-phase MEK concentration along the biofilter height. The model 2 is solved, reproduced and compared with

Fig. 6 Model 2 (with high MEK inhibition) prediction of different MEK gas-phase concentrations along the biofilter height for the gas flow rate of $0.03 \text{ m}^3 \text{ h}^{-1}$

Table 3 Model 2 parameters (with high concentrations)

Parameter	Value	Unit
$\mu_{\max}$	0.58	h^{-1}
K_m	5.34	g m^{-3}
a	0.0017	h^{-1}
K_I	2.66	g m^{-3}
$V_{\max, \max}$	123.1	$\text{g pollutant m}^{-3} \text{ of biofilter h}^{-1}$
H_{CC}	0.276

Fig. 7 Model 3 (with flow rate modification) prediction of MEK gas-phase concentrations along the biofilter height for different gas flow rate at a inlet MEK gas-phase concentration is 1.2 gm^{-3}

experimental results of MEK removal using pressmud based biofilter. The kinetic parameters of model 2 was given in Table 3. Figure 7 shows the solution of model 2 with high inlet MEK concentration and compared with the experimental results. Reproduced model solutions and experimental data are in good agreement.

Biofilter model 3

Model 3 developed by Li and De Visscher accounts for the effect of varying air flow rate. In this case, Eq. (2) combined with Eqs. (10)–(12) must be solved simultaneously. The model solutions are reproduced and were compared with experimental results. Table 4 shows the parameters taken.

Pressmud was used as a packing material with microbial flora present in the Pressmud. The solution to model 3 using the parameters in Table 4 are obtained for four different flow rates 0.03, 0.06, 0.09 and $0.12 \text{ m}^3 \text{ h}^{-1}$. Figure 8 shows the simulation results with the experimental data for all the flow rates. On the same graph, experimental results were also compared with model 2 which neglect the effect of air flow rate variation. Model 2 shows wider variation with the experimental data than the simulation results presented by Li

Table 4 Model 3 parameters (with gas flow rate)

Parameter	Value	Unit
$\mu_{\max}$	0.12	h^{-1}
K_m	11.1	g m^{-3}
a	0.0017	h^{-1}
K_i	2.66	g m^{-3}
$V_{\max, \max}$	869.3	$\text{g pollutant m}^{-3} \text{ of biofilter h}^{-1}$
p	0.6325	
H_{CC}	0.422

Fig. 8 Effect of changing $\mu/\mu_{\max}$ in model 1 for the inlet MEK concentration of 0.2 gm^{-3} at an gas flow rate of $0.03 \text{ m}^3 \text{ h}^{-1}$ on the efficiency

and De Visscher. This indeed confirms that flow rate modification is an important factor which should not be ignored.

Sensitivity analysis

A sensitivity analysis of model 1–3 is performed to study the effect of the actual maximum specific growth μ (rate on the removal efficiency of MEK). The μ effect of changing with all other parameters fixed $\mu_{\max}$ as in Table 2 is shown in Fig. 9. An increase in μ leads to an increase in the removal efficiency of MEK in case of model 1. However, percent removal efficiency (%RE) asymptotically reaches a maximum value at μ of 0.90 h^{-1} . In case of model 2 (High inlet MEK Concentration), $\mu_{\max}$ the effect of changing, while keeping other parameters in Table 3 constant, is shown in Fig. 10. Again, an increase in the maximum specific growth rate increases the removal efficiency up to a certain limit, after which the change is negligible. Since model 3 is very similar to model 2, the effect of changing the actual maximum specific growth rate will be the same as in case of model 2.

Fig. 9 Effect of changing $\mu/\mu_{\max}$ in model 2 for the inlet MEK concentration of 1.2 gm^{-3} at an gas flow rate of $0.03 \text{ m}^3 \text{ h}^{-1}$ on the removal efficiency **Fig. 10** Effect of changing K_m in model 1 (at low concentration) on removal efficiency (RE)

Effect of Michaelis–Menten constant (K_m)

The effect of changing the Michaelis–Menten constant (K_m) on the removal efficiency was studied. In case of model 1, all parameters in Table 2 were fixed and the Michaelis–Menten constant was changed. The experimental K_m value was 1.24 gm^{-3} . The effect of changing K_m on removal efficiency in model 1 is depicted in Fig. 11. For model 1 that neglects substrate inhibition, an increase in the value of the Michaelis–Menten constant (K_m) results in a decrease in removal efficiency. The same trend was observed at different inlet MEK gas phase concentrations. In case of model 2 with substrate inhibition, the effect of changing K_m , while keeping other parameters in Table 2 constant, is shown in Fig. 12 for inlet MEK gas-phase concentration is 1.2 gm^{-3} . Again, an increase in the value

Fig. 11 Effect of changing K_m in model 2 (at high MEK concentration) on removal efficiency (RE)

Fig. 12 Effect of changing a/a^{exp} in model 2 on removal efficiency (RE) of MEK

of the Michaelis–Menten constant (K_m) results in a decrease in removal efficiency. Since model 3 is very similar to model 2, the effect of changing K_m will be the same as in case of model 2.

Conclusion

The performance of a biofilter column packed with pressmud was evaluated for a period of 200 days using acclimated mixed culture. The biofilter column showed removal efficiency as high as 97.9 %. The removal efficiency decreased to 82 % when inlet concentration was increased to 1.2 g m^{-3} . The results established the fact that the biofilter performed well for lower to medium inlet MEK concentrations owing to the development of sufficient microbial concentration. The MEK biofilter model of Li and De Visscher is solved and compared with these data. The model is in very good agreement with the experimental data. Thus, the model can be used as a good approximation for full scale biofilter design calculations, particularly for MEK removal. A

sensitivity analysis of the three models is performed. Maximum specific growth rate, kinetic constant (K_m), and inhibition constants are more sensitive to removal efficiency than decay rate constant. Thus, accurate estimation of these parameters is important. Although the model does not provide an insight into the nature of the limiting factors such as oxygen effects and diffusion limitations involved in the biofiltration process, the model is simple and will enable designing of biofilters using fewer biofilter parameters.

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