Problem Set 9 —Key

CENG 340–Introduction to Environmental Engineering

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1. *(12.5 pts)* **Monod Kinetics**

A kinetic study of the bacterial utilization of methanol was conducted and yielded the following data:

Substrate, S (mg/L)	dS/dt ($\frac{\text{mg}}{\text{L}\times\text{hr}}$)
2	1
4	1.5
6	1.8
8	2
10	2.14

S = concentration of methanol.

In addition, biomass concentration (bacterial concentration, X) was maintained at a constant 100 mg/L during the study.

(a) From this data, determine the parameters for a Monod substrate utilization model, presented below.

$$-\frac{\mathrm{dS}}{\mathrm{dt}} = \frac{\mu_{\max}\mathrm{XS}}{\mathrm{K_s} + \mathrm{S}} \tag{1}$$

The model was fit to Eq.1 using Kaleidagraph's non-linear curve fitting package. The data and model fit are presented in Figure 1.

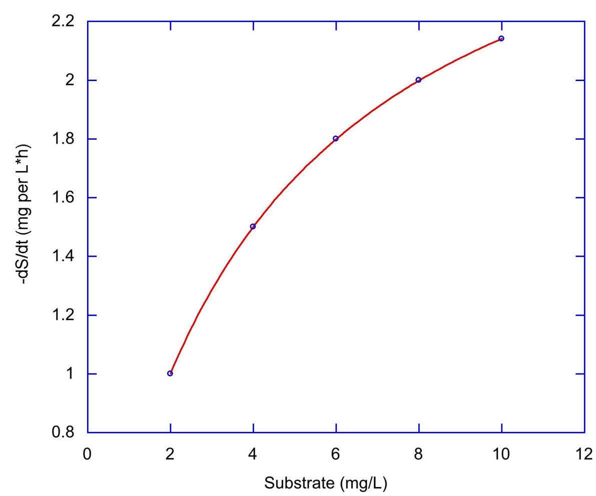

Figure 1: Growth rate of microroganisms as a function of substrate concentration. Circles represent data and the line represents a model fit.

The fitted parameters are as follows:
$\mu_{max} = 0.03 \ \frac{\mathrm{mg\,S}}{\mathrm{mg\,X \times h}} = 0.72 \ \frac{\mathrm{mg\,S}}{\mathrm{mg\,X \times day}}$

$\mathrm{K_s} = 4$ mg/L

(b) This model can be used to predict the concentration of methanol in a well-mixed pond that has an indigenous bacteria population close to that used in the kinetic study above.The concentration of the bacteria in the pond is, however, 10% of that of the kinetic study, and this bacterial concentration is relatively constant in the pond. Determine the methanol concentration in the pond 5 days after the pond was contaminated with 200 mg/L of methanol. Assume the pond behaves as a batch reactor (no inflow/outflow) and that no methanol escapes by evaporation. Hint: employ the "diphasic" or "mixed-order" Monod model.

Since S is much bigger than K_s, Eq. 1 simplifies to a zero-order equation presented as Eq. 2:

$$-\frac{\mathrm{dS}}{\mathrm{dt}} = \mu_{\mathrm{max}}\mathrm{X} \tag{2}$$

Eq. 2 can be integrated, resulting in Eq. 3:

$$-(\mathrm{S(t)} - \mathrm{S(0)}) = \mu_{\mathrm{max}}\mathrm{Xt} \tag{3}$$

Eq. 3 can be rearranged resulting in Eq. 4:

$$\mathrm{S(t)} = \mathrm{S(0)} - \mu_{\mathrm{max}}\mathrm{Xt} \tag{4}$$

Inputting numbers results in:

$$\mathrm{S(5)} = 200\,\frac{\mathrm{mg}}{\mathrm{L}} - 0.72\,\frac{\mathrm{mg\,S}}{\mathrm{mg\,X \times day}} \times 10\,\frac{\mathrm{mg\,X}}{\mathrm{L}} \times 5\,\mathrm{day}$$

S = 164 mg/L, which is still much bigger (at least one order of magnitude bigger) than K_s. In other words, the zero-order equation is still valid.

$$\mathrm{S} = \frac{\mathrm{K_s}(1 + \mathrm{k_d}\theta_\mathrm{c})}{\theta_\mathrm{c}(\mu_{\mathrm{max}} - \mathrm{k_d}) - 1}$$

$$\theta_{\mathrm{c(min)}} = \frac{1}{\mu_{\mathrm{max}} - \mathrm{k_d}}$$