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Some BOD problems

Practice, Practice, Practice

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Practice Problem #1

200 mL of Genesee river water was collected from just below the brewery. 2 mL of river water diluted to 1 L, aerated and seeded. The dissolved oxygen content was 7.8 mg/L initially. After 5 days, the dissolved oxygen content had dropped to 5.9 mg/L. After 20 days, the dissolved oxygen content had dropped to 5.3 mg/L. What is the ultimate BOD?

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Solution

We have multiple data points – so we don't need to assume the rate constant, k, to be 0.23 $days^{-1}$.

How would you use the data to calculate k?

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The equation

BODE = BOD $(1-e^{-kt})$

The problem is, we have 4 unknowns.

So, even if we know 2 of them (for example, the BODE at a given time), we still have 2 left.

2 unknowns require 2 equations to determine them

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The equation

BODE = BOD $(1-e^{-kt})$

k is a constant

BOD is a constant

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The equation

BOD_5 = BOD $(1-e^{-k(5\ \text{days})})$

BOD_{20} = BOD $(1-e^{-k(20\ \text{days})})$

If we compare the ratio, the BOD cancels.

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The equation

$$\frac{BOD_5}{BOD_{20}} = \frac{BOD\,(1-e^{-k(5\text{ days})})}{BOD\,(1-e^{-k(20\text{ days})})}$$

$$\frac{BOD_5}{BOD_{20}} = \frac{(1-e^{-k(5\text{ days})})}{(1-e^{-k(20\text{ days})})}$$

And we know BOD_5/BOD_{20}. It's just a number, call it Q

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The equation

$$Q = \frac{(1-e^{-k(5\text{ days})})}{(1-e^{-k(20\text{ days})})}$$

And we just solve for k…

How would you do that?

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The equation

$Q(1-e^{-k(20\text{ days})}) = (1-e^{-k(5\text{ days})})$

$Q - Q\,e^{-k(20\text{ days})}) = 1-e^{-k(5\text{ days})}$

$e^{-k(5\text{ days})} - Q\,e^{-k(20\text{ days})} = 1 - Q$

Easiest thing to do then is graph it.

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For our particular problem:

200 mL of Genesee river water was collected from just below the brewery. 2 mL of river water diluted to 1 L, aerated and seeded. The dissolved oxygen content was 7.8 mg/L initially. After 5 days, the dissolved oxygen content had dropped to 5.9 mg/L. After 20 days, the dissolved oxygen content had dropped to 5.3 mg/L. What is the ultimate BOD?

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Solution

$$BOD_5 = \frac{7.8\ mg/L - 5.9\ mg/L}{2\ mL/1000\ mL} = 950\ mg/L$$

$$BOD_{20} = \frac{7.8\ mg/L - 5.3\ mg/L}{2\ mL/1000\ mL} = 1250\ mg/L$$

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$$\frac{BOD_5}{BOD_{20}} = \frac{(1-e^{-k(5\ days)})}{(1-e^{-k(20\ days)})}$$

$$\frac{950}{1250} = \frac{(1-e^{-k(5\ days)})}{(1-e^{-k(20\ days)})}$$

$$0.76 = \frac{(1-e^{-k(5\ days)})}{(1-e^{-k(20\ days)})}$$

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$0.76 = \frac{(1-e^{-k(5\text{ days})})}{(1-e^{-k(20\text{ days})})}$

$0.76 - 0.76\, e^{-k(20)} = 1 - e^{-k(5)}$

$e^{-k(5)} - 0.76\, e^{-k(20)} = 1 - 0.76 = 0.24$

We just graph the left side as a function of k and look to see where it equals 0.24 (or you can use solver on your calculator)

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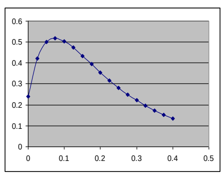

k	e^-5k - 0.76e^20k
0	0.24
0.025	0.421534
0.05	0.499212
0.075	0.51771
0.1	0.503676
0.125	0.472877
0.15	0.434528
0.175	0.393912
0.2	0.35396
0.225	0.31621
0.25	0.281384
0.275	0.249734
0.3	0.221246
0.325	0.195769
0.35	0.173081
0.375	0.152935
0.4	0.13508

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The k value is…

$0.28\ \text{day}^{-1}$

You can then use this and either of the BODE to calculate ultimate BOD

$BOD_5 = BOD\,(1-e^{-k(5\text{ days})})$

$950\text{ mg/L} = BOD\,(1 - e^{-(0.28)(5)})$

$BOD = 1261\text{ mg/L}$

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Comparison to Theoretical

If we had simply assumed $k=0.23\ days^{-1}$

$BOD_5 = BOD\,(1-e^{-k(5\ days)})$
$950\ mg/L = BOD\,(1 - e^{-(0.23)(5)})$
BOD = 1390 mg/L

And, if we calculated the BOD from the 20 day data…

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UGH!

$BOD_{20} = BOD\,(1-e^{-k(20\ days)})$
$1250\ mg/L = BOD\,(1 - e^{-(0.23)(20)})$
BOD = 1262 mg/L

The ultimate BOD will not agree since the k is "wrong".

Which would you use?

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20 day is always better

20 day should always be more accurate. You are averaging more days AND the reaction should be 90+% complete by then (actually 99% if the assumed k is even close to correct)

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Practice Problem #2

200 mL of Genesee river water was collected from just below the brewery. 2 mL of river water diluted to 250 mL, aerated and seeded. The dissolved oxygen content was 7.6 mg/L initially. After 5 days, the dissolved oxygen content had dropped to 5.7 mg/L. A second sample was obtained 60 days later and retested in identical fashion. The intial dissolved oxygen was 7.5 mg/L and, after 5 days, dropped to 5.3 mg/L. What is the ultimate BOD for each of the samples? Which water sample was cleaner?

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Solution

$$BOD_{5,1} = \frac{7.6\text{ mg/L} - 5.7\text{ mg/L}}{2\text{ mL}/250\text{ mL}} = 238\text{ mg/L}$$

$$BOD_{5,2} = \frac{7.5\text{ mg/L} - 5.3\text{ mg/L}}{2\text{ mL}/1000\text{ mL}} = 275\text{ mg/L}$$

Can you already tell which is dirtier?

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Solution

Can you already tell which is dirtier?

Since k is constant, the BOD_5 is as good a measure as the ultimate BOD. The 2nd test sample is dirtier than the first.

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Ultimate BOD calculation

Sample #1

$BOD_5 = BOD\,(1 - e^{-k(5\ \text{days})})$

238 mg/L = BOD $(1 - e^{-(0.23)(5)})$

238 mg/L = BOD (0.6833)

BOD = 348 mg/L

Sample #2

275 mg/L = BOD (0.6833)

BOD = 402 mg/L

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BUT BUT BUT

Always keep in mind the limitations of any test:

BOD is not foolproof: the biggest fault being that it will miss humus (non-biodegradable organic compounds).

Generally, if it is wrong, it is too low. Although it can also erroneously detect chemical oxidation of inorganic compounds (metals) – but this is smaller than the humus problem.