Exercise_006-1

(This exercise requires typeset answers)

In a standard 5-day BOD test,

a) Why is the BOD bottle stoppered?
b) Why is the test run in the dark (or in a black bottle)?
c) Why is it usually necessary to dilute the sample?
d) Why is it necessary to seed the sample ?
e) Why is ultimate BOD not measured?

a) To prevent reaeration from atmosphere

b) To prevent algae from producing O_2 by photosynthesis

c) To prevent using all oxygen originally present in sample – otherwise cannot measure O_2 actually used

d) Because necessary organisms to exert O_2 demand may be absent

e) Takes too long, especially at low DO (late time in degradation history)

Exercise_006-2

Incoming wastewater, with BOD_5 nominally equal to 200mg/L but known to vary as much as 10% (+/- 20 mg/L) is treated in a well-operated secondary treatment plant that removes 90% of the BOD. You are to ***design*** a 5-day BOD test with a standard 300mL bottle, using a mixture of treated sewage and dilution water (no seed). Assume the initial DO is 9.2 mg/L.

a) Determine the maximum design volume of wastewater to put into the BOD bottle if you want at least 2.0 mg/L of DO at the end of the test (the remainder of the water will be dilution water), and your test must accommodate the entire range of expected BOD concentrations.
b) Determine the minimum design volume of wastewater to put into the BOD bottle if you want at least a 2.0 mg/L decline in DO at the end of the test (the remainder of the water will be dilution water), and your test must accommodate the entire range of expected BOD concentrations.
c) At the nominal BOD5 value, if you make a mixture of ½wastewater and ½diluent, what DO would you expect after 5 days?

Approach.
- do a), b), c) at nominal value.
repeat at + 10%, -10% - report conservative results.

a) $DO_i - DO_5 \left(\frac{V_w + V_d}{V_w}\right)$

BODwaste range 220 - 180 mg/L
BOD treated → 22 - 18 mg/L

$$(9.2 - 2.0)\left(\frac{V_w + V_d}{V_w}\right) = 18 - 22 \text{ mg/L}$$

$$7.2\left(\frac{V_w + V_d}{V_w}\right) = 18 - 22 \text{ mg/L}$$

$$\frac{7.2(300\text{mL})}{18 - 22} = V_w$$

Maximum Volumes

V_w = 120mL (18mg/L BOD)
98mL (22mg/L BOD)

b) $$(9.2 - 7.2)\left(\frac{V_w + V_d}{V_w}\right) = 18 - 22 \text{mg/L}$$

$$\frac{2(300)}{18 - 22} = V_w$$

V_w = 33.3mL (18mg/L BOD)
27.3mL (22mg/L BOD

continued.

So for a min DO. Maximum value is 98mL

for a ΔDO of at least 2 mg/L Minimum value is 33 mL

∴ Recommended BOD protocol

Add at least 30 mL waste to dilution water, no more than 98 mL to accomodate expected range of BODs.

- Probably best to use lower dose 30 mL as this could help detect plant failure well above 22 mg/L BOD

c) $9.2 - 20\,mg/L\left(\frac{V_w}{V_w + V_d}\right) = DO_5$

$\frac{150}{300} = \frac{1}{2}$

$9.2 - 10 = 0$

∴ Expect all O_2 to be used up thus measured DO will be near zero.

Exercise_006-3

(This exercise requires typeset answers – but any calculations can be handwritten)

The following data were obtained for a BOD test that was made to evaluate how a plant was operating. Analyze the data to determine the %-BOD being removed by the plant. If the plant is supposed to remove a nominal value of 85% of the BOD, would you say the plant is operating properly? Prepare a brief explaination for your answer.

	Initial DO (mg/L)	Final DO (mg/L)	V_{waste} (mL)	$V_{diluent}$ (mL)
Untreated Sewage	6.0	2.0	5	295
Treated Sewage	9.0	4.0	15	285

Untreated

$$BOD_5 = \frac{DO_i - DO_f}{P}$$

$$= \frac{6.0 - 2.0}{5/300} = 240 mg/L$$

Treated

$$BOD_5 = \frac{DO_i - DO_f}{P}$$

$$= \frac{9.0 - 4.0}{15/300} = 100 mg/L$$

% removal

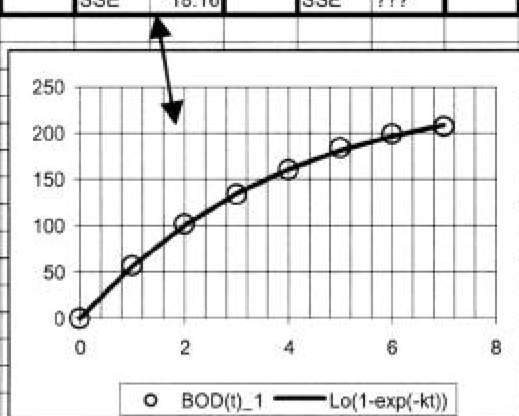
$$\% BOD_{removal} = \frac{240 - 100}{240} = 0.583 \times 100 = 58.3\%$$

Target is 85% nominal. If plant variability was +/- 15% (i.e. 100% - 70%, the calculated value is still outside this range) ∴ Reasonable conclusion is plant is not operating properly

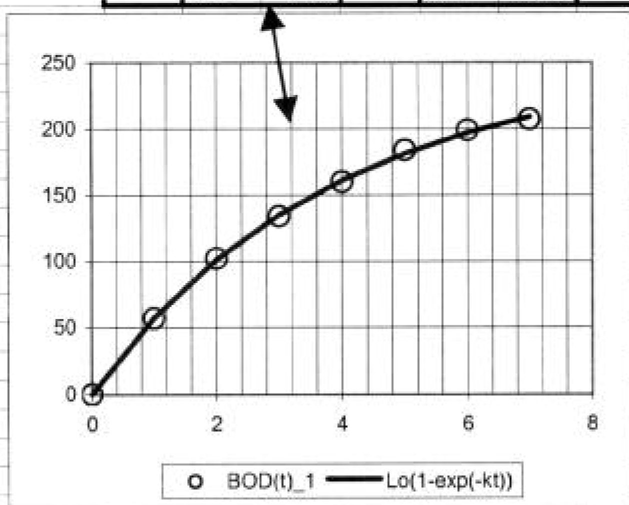
Exercise_006-4

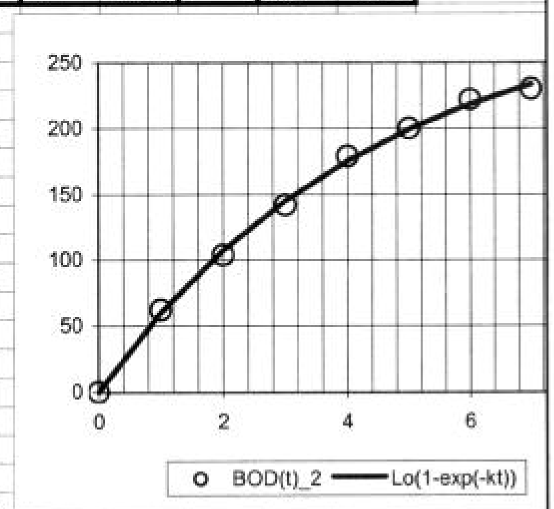
The following data are for four wastewater samples. Determine the L_o (ultimate BOD) for these four wastes by plotting the data and using the EXCEL solver feature to fit an exponential curve to each of the data series. Fit the curve by minimization of the sum of squared error (SSE on the spreadsheet), by changing cells for k and L_o. Report the L_o and decay constant. Repeat the analysis using the method in problem 5.14 of the textbook for L_o. Compare the two results (the values of Lo should be pretty close by either method). The spreadsheet depicted below is available on the course website.

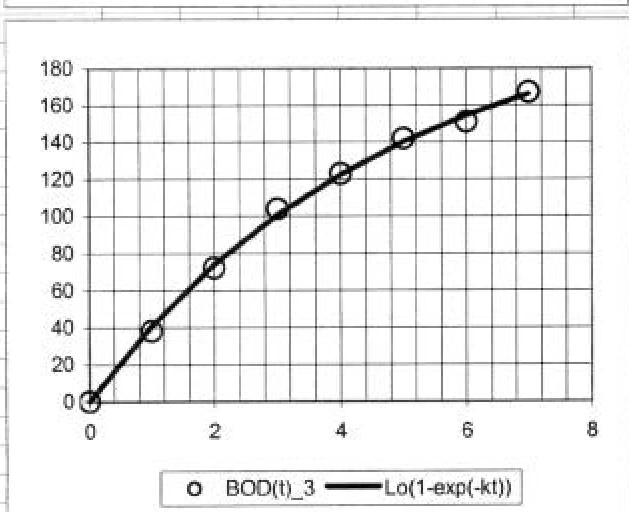
	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Waste_1			Waste_2			Waste_3			Waste_4		
2		k	0.26		k	???		k	???		k	???	
3		Lo	249.35		Lo	???		Lo	???		Lo	???	
4	Time(day)	BOD(t)_1	Lo(1-exp(-kt))	Error^2	BOD(t)_2	Lo(1-exp(-kt))	Error^2	BOD(t)_3	Lo(1-exp(-kt))	Error^2	BOD(t)_4	Lo(1-exp(-kt))	Error^2
5	0	0	0.00	0.00	0	???	???	0	???	???	0	???	???
6	1	57	57.09	0.01	62	???	???	38	???	???	41	???	???
7	2	102	101.11	0.80	104	???	???	72	???	???	79	???	???
8	3	134	135.05	1.10	142	???	???	104	???	???	101	???	???
9	4	160	161.22	1.48	179	???	???	123	???	???	121	???	???
10	5	184	181.40	6.79	200	???	???	142	???	???	140	???	???
11	6	199	196.95	4.19	222	???	???	151	???	???	152	???	???
12	7	207	208.95	3.80	230	???	???	167	???	???	159	???	???
13			SSE	18.16		SSE	???		SSE	???		SSE	???

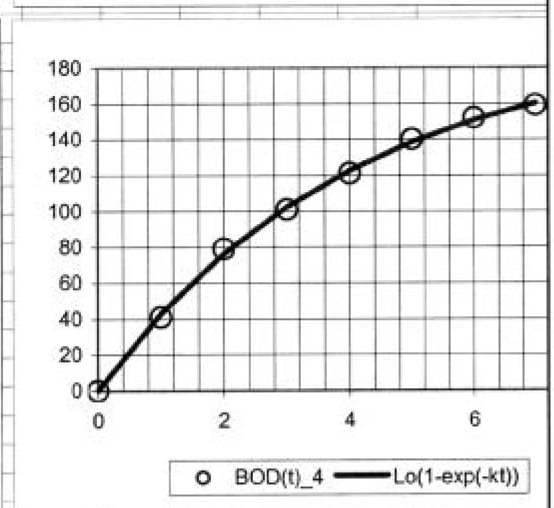


	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Waste_1			Waste_2			Waste_3			Waste_4		
2		k	0.26		k	0.23		k	0.21		k	0.25	
3		Lo	249.35		Lo	293.57		Lo	215.99		Lo	194.10	
4	Time(day)	BOD(t)_1	Lo(1-exp(-kt))	Error^2	BOD(t)_2	Lo(1-exp(-kt))	Error^2	BOD(t)_3	Lo(1-exp(-kt))	Error^2	BOD(t)_4	Lo(1-exp(-kt))	Error^2
5	0	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
6	1	57	57.09	0.01	62	59.69	5.36	38	40.80	7.85	41	42.89	3.56
7	2	102	101.11	0.80	104	107.24	10.48	72	73.89	3.59	79	76.30	7.30
8	3	134	135.05	1.10	142	145.12	9.74	104	100.74	10.65	101	102.33	1.76
9	4	160	161.22	1.48	179	175.30	13.67	123	122.51	0.24	121	122.61	2.58
10	5	184	181.40	6.79	200	199.35	0.43	142	140.17	3.36	140	138.40	2.55
11	6	199	196.95	4.19	222	218.50	12.22	151	154.49	12.19	152	150.71	1.67
12	7	207	208.95	3.80	230	233.77	14.18	167	166.11	0.79	159	160.30	1.68
13			SSE	18.16		SSE	66.08		SSE	38.66		SSE	21.10

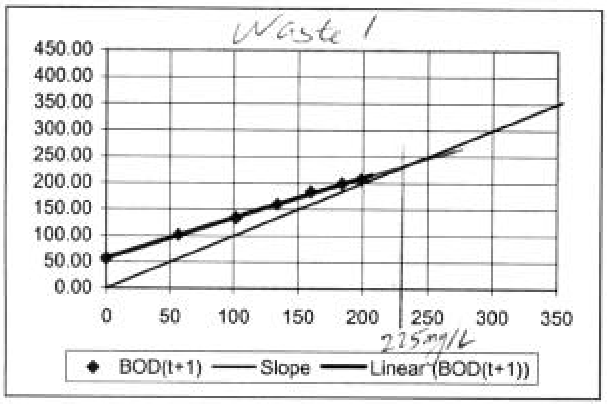


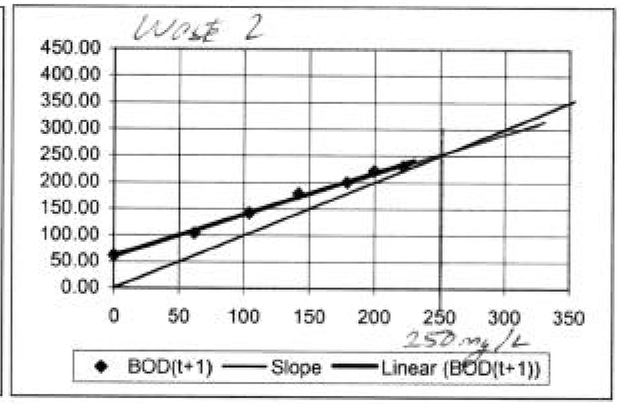


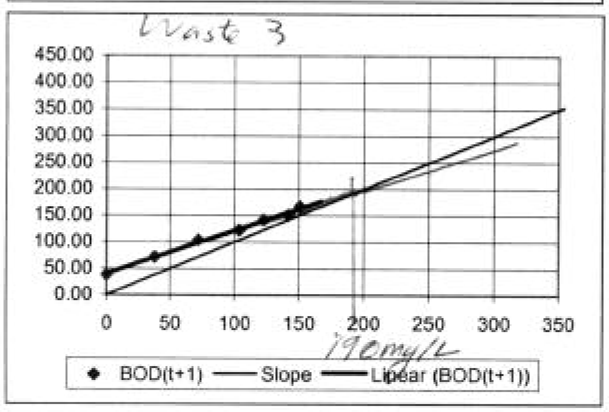


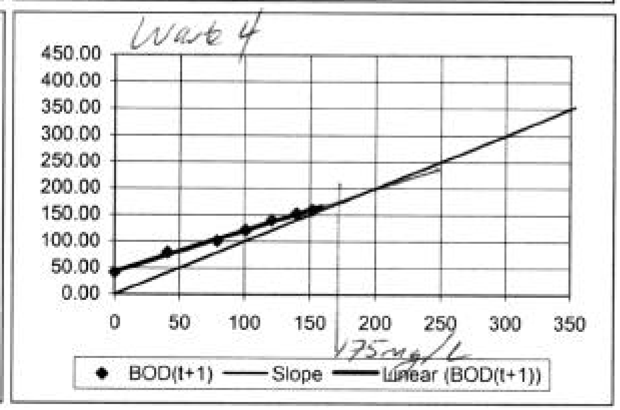


Time(day)	Waste_1 BOD(t)_1	Waste_1 BOD(t+1)	Waste_1 Slope	Waste_2 BOD(t)_2	Waste_2 BOD(t+1)	Waste_2 Slope	Waste_3 BOD(t)_3	Waste_3 BOD(t+1)	Waste_3 Slope	Waste_4 BOD(t)_4	Waste_4 BOD(t+1)	Waste_4 Slope
0	0	57.00	0.00	0	62.00	0.00	0	38.00	0.00	0	41.00	0.00
1	57	102.00	57.00	62	104.00	62.00	38	72.00	38.00	41	79.00	41.00
2	102	134.00	102.00	104	142.00	104.00	72	104.00	72.00	79	101.00	79.00
3	134	160.00	134.00	142	179.00	142.00	104	123.00	104.00	101	121.00	101.00
4	160	184.00	160.00	179	200.00	179.00	123	142.00	123.00	121	140.00	121.00
5	184	199.00	184.00	200	222.00	200.00	142	151.00	142.00	140	152.00	140.00
6	199	207.00	199.00	222	230.00	222.00	151	167.00	151.00	152	159.00	152.00
7	207		207.00	230		230.00	167		167.00	159		159.00
	300		300.00	300		300.00	300		300.00	300		300.00
	400		400.00	400		400.00	400		400.00	400		400.00









Compare to Solver method

	2-parameter	slopes
Wase 1	250mg/L	225mg/L
2	290mg/L	250mg/L
3	215mg/L	190mg/L
4	195mg/L	175mg/L

} relatively close. Probably more accurate if a larger scale graphics is used.

Exercise_006-5

A wastewater has BOD5 equal to 180 mg/L and a reaction rate k equal to 0.22/day. It also has a TKN value of 30 mg/L.

a) Find the ultimate carbonaceous oxygen demand (CBOD).
b) Find the ultimate nitrogeneous oxygen demand (NBOD).
c) Find the remaining BOD (nitrogeneous + carbonaceous) after five days.

a) $L_0 = \frac{BOD_5}{(1-e^{-kt})} = \frac{180 mg/L}{(1-e^{-0.22(5)})} = 269.81 = 270 mg/L$

b) $NBOD_U = 30 mg/L \cdot \frac{17 g\ NH_3}{14 g\ N} \cdot \frac{64 g\ O_2}{17 g\ NH_3} = 137 mg/L$

c) $L_5 = L_0 - BOD_5 = 270 mg/L - 180 mg/L = 90 mg/L$

CIVE 3331 Environmental Engineering

Exercise_006-6

Suppose some pond water contains 10.0 mg/L of algae that can be represented chemically as $C_6H_{15}O_6N$. Using the following reactions to estimate the theoretical carbonaceous oxygen demand and the total theoretical nitrogenous oxygen demand.

$$C_6H_{15}O_6N + 6O_2 \Rightarrow 6CO_2 + 6H_20 + NH_3$$

$$NH_3 + 2O_2 \Rightarrow NO_3^- + H^+ + H_2O$$

$MW_{algae} = (6)(12) + (15)(1) + (6)(16) + (14)(1) = 197\ g/mol$

~~CBOD~~ CThOD

6 mol O_2 oxidizes 1 mol algae $(6)(32) = 192\ g\ O_2/mol$ algae

$$CThOD = \frac{10 mg\text{-}algae}{L} \cdot \frac{192 g\ O_2}{1 mol\ algae} \cdot \frac{1 mol\ algae}{197 g} = 9.75 mg/L$$

NThOD

1 mol NH_3 (17g) uses 2 mol O_2 (64 g)

$$NThOD = \frac{10 mg\ algae}{L} \cdot \frac{17 g\ NH_3}{1 mol\ algae} \cdot \frac{1 mol\ algae}{197 g} \cdot \frac{64 g\ O_2}{17 g\ NH_3} = 3.25 mg/L$$