Example 8.1

A sludge batch is submitted to aerobic digestion. In Table 8.2 experimental results are presented for the variations in (1) OUR, (2) suspended solids, (3) alkalinity, and (4) nitrate concentration, as a function of the digestion time (van Haandel et al, 1986). The sludge was taken from an activated sludge system operated at a sludge age of 4 days and the temperature was controlled at 22°C. Determine the decay constant b_h from these data, according to the four methods presented above.

Table 8.2 Experimental results of aerobic digestion of a batch of active sludge

Time	O_t	Time	X_v	N_n	Alkalinity
days	mg $O_2.l^{-1}.h^{-1}$	days	mg $VSS.l^{-1}$	mg $VSS.l^{-1}$	ppm $CaCO_3$
0	43.6	0	4560	37	725
0.18	20.4	0.5	4100	69	585
0.82	33.5	1.0	3880	92	520
1.10	28.7	1.5	-	109	488
1.35	27.8	2.0	3840	110	435
1.87	25.1	2.5	3710	126	365
2.32	20.2	3.0	3490	138	355
2.87	18.9	3.5	3380	142	335
3.09	16.0	4.0	3320	158	295
3.33	16.5	4.5	3080	162	245
3.88	13.8	5.0	3080	178	222
4.17	12.4	5.5	-	185	175
4.41	13.0	6.0	2980	192	155
4.87	11.4				
5.26	10.1				
6.00	10.5				

Solution:

The calculations to determine the decay constant b_h can be summarised as follows:

(1) Plot the oxygen demand O_t as a function of the digestion time on semi log paper and determine the decay constant from the slope of the best-fit straight line through the experimental points as shown in Fig. 8.3a. The intersection of the line with the vertical axis can be used to estimate the initial active sludge concentration. By extrapolating to t = 0 in Fig. 8.3a, the value of $\ln(O_t)$ can be estimated as 3.65 so that $O_{t,i}$ = 38.5 mg $O_2.l^{-1}.h^{-1}$. With the aid of Eq. (8.13):

$$O_{t,i} = (f_{cv} + 4.57 \cdot f_n) \cdot (1 - f) \cdot b_h \cdot X_{ai} \cdot \exp(-b_h \cdot t)$$
$$= (1.5 + 0.457) \cdot (1 - 0.2) \cdot 0.25 \cdot X_{ai} = 38.5 \cdot 24 \text{ or } X_{ai} = 2355 \text{ mg VSS.l}^{-1}$$

(2) Since the digestion was only applied for a period of 6 days there are no data available for complete digestion. However the value of the initial active sludge concentration can be used to estimate these values. For t = 0 the volatile sludge concentration X_{vi} = 4435 mg $VSS.l^{-1}$. After complete decay of the active sludge, the reduction of the volatile sludge concentration will be: $X_{ai} \cdot (1 - f)$ = 1885 mg $VSS.l^{-1}$ so that the final volatile sludge concentration is given by $X_{v\infty}$ = 4435 - 1885 = 2550 mg $VSS.l^{-1}$. Similarly the final values for nitrate and alkalinity are calculated as: $N_{n\infty}$ = 240 mg $N.l^{-1}$ and Alk_∞ = 10 ppm $CaCO_3$.

(3) Plot the experimental data of (X_v -$X_{v\infty}$) as a function of the digestion time on semi log paper and determine the slope. If the data has a systematic tendency of deviating from a straight line (either convex or concave) the estimate for the final volatile solids concentration has been incorrect and must be reviewed.

(4) Plot the experimental data of (N_{ni}–$X_{n\infty}$) and (Alk_i - Alk_∞) as a function of the digestion time on semi log paper and determine the corresponding decay constants.

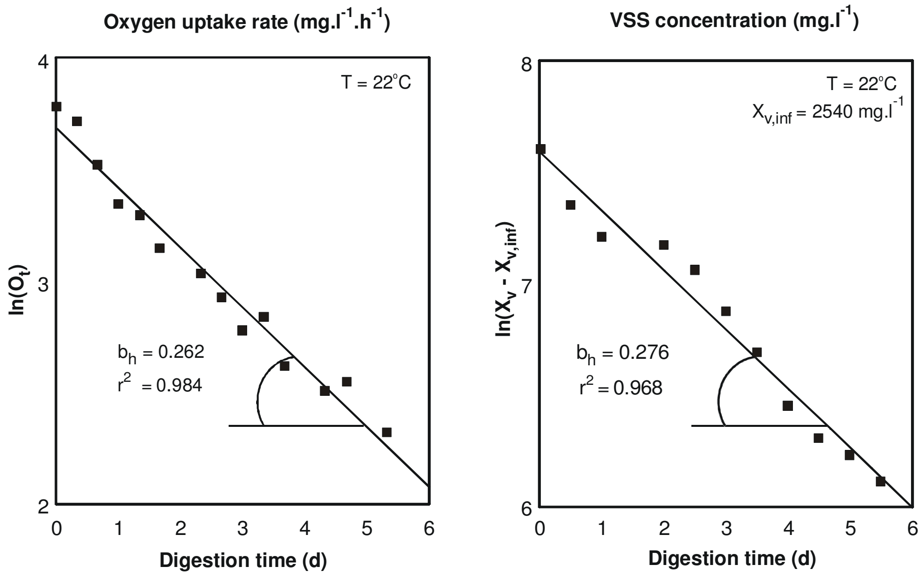

Figure 8.3 Determination of the decay rate b_h using the change in oxygen uptake rate (O_t) and volatile sludge concentration (X_v) - Example 8.1

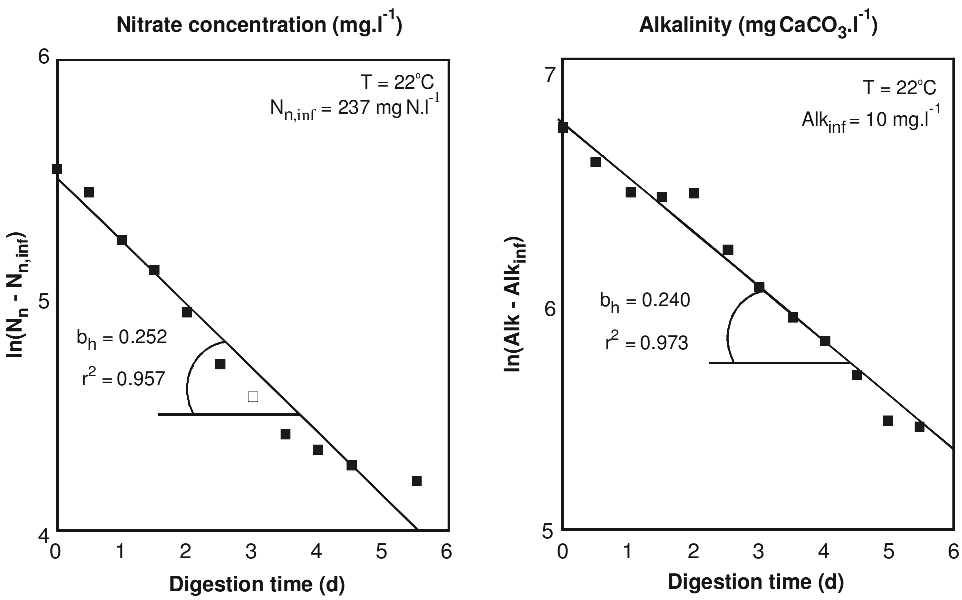

Figure 8.3 continued - Determination of the decay rate b_h using the change in the nitrate concentration (N_n) and the alkalinity (Alk)

In Fig. 8.3 the experimental data of Table 8.2 are shown for each of the four methods, together with the best fit of the decay rate b_h. For all methods it can be observed that the straight lines predicted by theory correlate closely to the experimental data points. This allows determination of the value of the decay constant by no less than four independent methods. The results of the four determinations are practically equal while the small differences can be attributed to measurement errors. Hence the best estimate for the value of the decay constant is the average of the four obtained values:

$$b_{h22} = (0.262 + 0.276 + 0.252 + 0.240)/4 = 0.26\ d^{-1}$$