

Example 5.2:

Determine the potential removal of phosphorus from the influent, as well as the main other system parameters of an UCT system treating municipal waste water. Assume the following characteristics and conditions: $Q_i = 1000 \text{ m}^3 \cdot \text{d}^{-1}$; $S_{bi} = 500 \text{ mg COD} \cdot \text{l}^{-1}$; $f_{ns} = f_{np} = 0.1$; $f_{sb} = 0.25$; $f_{an} = 0.15$; $f_{x1} = 0.35$, $R_s = 10 \text{ d}$; $\text{Temp.} = 20 \text{ }^\circ\text{C}$ and $r = 1$.

Solution:**(1) Determine the amount of VFA formed in the anaerobic zone:**

When it is assumed that all easily biodegradable material in the influent is converted into VFA then:

$$S_{bs} = 0 \text{ and } S_{seq} = S_{bsi} = f_{sb} \cdot S_{bi} \text{ and}$$

$$MX_a = Q_i \cdot C_{rh} \cdot (S_{bi} - S_{bsi})$$

$$MX_a = 1000 \cdot 1.32 \cdot (400 - 100) / 1000 = 397 \text{ kg VSS}$$

Now the residual concentration of easily biodegradable material in the effluent of the anaerobic zone is calculated:

$$S_{bs} = [S_{bsi} / (1 + r)] / [1 + (f_{an} \cdot K_c \cdot MX_a / Q_i) / (1 + r)] \\ = (100/2) / (1 + (0.15 \cdot 0.06 \cdot 397 \cdot 1000) / 1000) = 17.9 \text{ mg COD} \cdot \text{l}^{-1}$$

The new value of S_{bs} is used to calculate MX_a as 445 kg VSS which in turn results in a new value for $S_{bs} = 16.7 \text{ mg COD} \cdot \text{l}^{-1}$. After the third iteration the following values are calculated: $MX_a = 441 \text{ kg VSS}$ and $S_{bs} = 16.7 \text{ mg COD} \cdot \text{l}^{-1}$, which are accepted as final values.

(2) Determine the concentration of the different sludge fractions:**a) Phosphate accumulating organisms:**

Use the concentration S_{bsi} at the inlet- and S_{bs} at the outlet of the anaerobic zone, to calculate the daily amount of organic material sequestered by the PAO:

$$MS_{seq} = Q_i \cdot (S_{bsi} - (r+1) \cdot S_{bs}) = 1000 \cdot (100 - 2 \cdot 16.7) / 1000 = 67 \text{ kg COD} \cdot \text{d}^{-1}$$

This allows the active mass of PAO to be calculated as:

$$C_{rp} = Y \cdot R_s / (1 + b_p \cdot R_s) = 0.45 \cdot 10 / (1 + 0.04 \cdot 10) = 3.21$$

$$MX_{ap} = C_{rp} \cdot MS_{seq} = 3.21 \cdot 67 = 214 \text{ kg VSS}$$

The endogenous residue generated during the decay of the PAO is defined as:

$$MX_{ep} = f_{ep} \cdot b_p \cdot R_s \cdot MX_{ap} = 0.25 \cdot 0.04 \cdot 10 \cdot 214 = 21.4 \text{ kg VSS}$$

b) Normal heterotrophic sludge:

The active sludge mass of the normal heterotrophic activated sludge has already been calculated above: $MX_a = 441$ kg VSS. So the endogenous residue generated during the decay of the normal sludge is:

$$MX_e = f \cdot b_h \cdot R_s \cdot MX_a = 0.2 \cdot 0.24 \cdot 10 \cdot 441 = 212 \text{ kg VSS}$$

c) Total and volatile sludge mass and production:

The amount of inert sludge is calculated from the inert particulate organic fraction in the influent:

$$MX_i = f_{np} \cdot MS_{ti} \cdot R_s / f_{cv} = 0.1 \cdot 500 \cdot 10 / 1.5 = 333 \text{ kg VSS}$$

The total mass of volatile sludge is calculated as:

$$MX_v = MX_a + MX_e + MX_i + MX_{ap} + MX_{ep} = 441 + 212 + 333 + 214 + 21 = 1221 \text{ kg VSS}$$

The total mass of sludge is given as:

$$MX_t = (MX_a + MX_e + MX_i + MX_{ep}) / 0.8 + MX_{ap} / 0.46 = 1724 \text{ kg TSS}$$

The production of excess sludge is calculated as a fraction $1/R_s$ of the total sludge mass:

$$ME_v = MX_v / R_s = 1221 / 10 = 122 \text{ kg VSS} \cdot d^{-1}$$

$$ME_t = MX_t / R_s = 1724 / 10 = 172 \text{ kg TSS} \cdot d^{-1}$$

d) Phosphorus removal:

The removal of phosphorus from the influent is given as a fraction of 0.38 of the mass of the active PAO discharged from the system and a fraction of 0.025 of the other volatile fractions:

$$MP_l = f_p \cdot (MX_a + MX_e + MX_i + MX_{ep}) / R_s + f_{pp} \cdot MX_{ap} / R_s = 10.7 \text{ kg P} \cdot d^{-1}$$

It is interesting to compare to compare the results obtained above for a mixed culture of PAO and normal biomass with those of an activated sludge system without anaerobic zone:

MX_a	$= C_r \cdot MS_{bi}$	$= 1.32 \cdot 400$	$= 528 \text{ kg VSS}$
MX_e	$= f \cdot b_h \cdot R_s \cdot MX_a$	$= 0.2 \cdot 0.24 \cdot 10 \cdot 528$	$= 253 \text{ kg VSS}$
MX_i	$= f_{ns} \cdot R_s \cdot MS_{ti} / f_{cv}$	$= 0.1 \cdot 10 \cdot 500 / 1.5$	$= 333 \text{ kg VSS}$
MX_v	$= MX_a + MX_e + MX_i$	$= 528 + 253 + 333$	$= 1114 \text{ kg VSS}$
MX_t	$= MX_v / 0.8$		$= 1392 \text{ kg TSS}$
ME_v	$= MX_v / R_s$		$= 111 \text{ kg VSS} \cdot d^{-1}$
ME_t	$= MX_t / R_s$		$= 139 \text{ kg TSS} \cdot d^{-1}$
MP_l	$= f_p \cdot ME_v$	$= 0.025 \cdot 111$	$= 2.8 \text{ kg P} \cdot d^{-1}$

It can be concluded that the volatile sludge amount in the conventional system is a fraction $1114/1221 = 90\%$ of the value of the mixed system with PAO. The total sludge amount is a fraction $1392/1724 = 80\%$. The removal of phosphorus in the conventional system is only a fraction $2.8/10.7 = 23\%$ of the system with the mixed culture.