

Example 3.4

A certain raw sewage ($f_{ns} = f_{np} = 0.10$) has the following characteristics: the ratio COD : TKN : P = 660 : 50 : 3; $T = 26^\circ\text{C}$ and $b_n = 0.3 \text{ d}^{-1}$. The waste water is treated in an activated sludge system operating at a sludge age of 8 days. Estimate the sludge production and the nitrogen and phosphorus concentrations in the effluent.

Solution:

From Fig. 3.10 the sludge production and the demand for N and P for a sludge age of 8 days are determined: $mE_v = 0.23 \text{ mg VSS} \cdot \text{mg}^{-1} \text{ COD}$; $mN_i = 0.023 \text{ mg N} \cdot \text{mg}^{-1} \text{ COD}$ (Eq. 3.59) and $mP_i = 0.0058 \text{ mg P} \cdot \text{mg}^{-1} \text{ COD}$ (Eq. 3.62) for $f_n = 0.1 \text{ mg N} \cdot \text{mg}^{-1} \text{ VSS}$ and $f_p = 0.025 \text{ mg P} \cdot \text{mg}^{-1} \text{ VSS}$. Hence the sludge production will be a factor 0.23 of the applied COD mass. The required influent nitrogen concentration for sludge production is:

$$N_i = mN_i \cdot S_{ii} = 0.023 \cdot 660 = 15 \text{ mg N} \cdot \text{l}^{-1}$$

Hence, if no nitrification takes place, the effluent nitrogen concentration will be:

$$N_{te} = N_{ii} - N_i = 50 - 15 = 35 \text{ mg N} \cdot \text{l}^{-1}$$

Similarly for phosphorus the required concentration for sludge production is:

$$P_i = mP_i \cdot S_{ii} = 0.0058 \cdot 660 = 3.8 \text{ mg P} \cdot \text{l}^{-1}$$

Hence, the concentration of phosphorus in the influent ($3.0 \text{ mg P} \cdot \text{l}^{-1}$) will be insufficient for sludge production and the difference between the demand and the available concentration ($3.8 - 3.0 = 0.8 \text{ mg P} \cdot \text{l}^{-1}$) must be added. Without this addition, problems may arise with poorly settling sludge. However, the phosphorus demand may be satisfied by supernatant return from the sludge digestion unit (See Chapter 8).

Example 3.5

A flow of $2000 \text{ m}^3 \cdot \text{d}^{-1}$ of an industrial waste water has a COD: TKN: P ratio of 1000 : 2 : 2. Under normal operational conditions the sludge production is $0.3 \text{ mg VSS} \cdot \text{mg}^{-1} \text{ COD}$. If DAP (di-ammonium phosphate $(\text{NH}_4)_2\text{HPO}_4$) and urea (NH_2CNH_2) are used to add the deficient nutrients required to compensate for losses with the excess sludge production, what will be the minimum concentrations of these compounds for the influent COD concentration of $1000 \text{ mg} \cdot \text{l}^{-1}$? It is known that urea is much cheaper than DAP.

Solution:

As $mE_v = 0.3 \text{ mg VSS} \cdot \text{mg}^{-1} \text{ COD}$ one has:

$$mN_l = f_n \cdot mE_v = 0.1 \cdot 0.3 = 0.03 \text{ mg N} \cdot \text{mg}^{-1} \text{ COD and}$$

$$mP_l = f_p \cdot mE_v = 0.025 \cdot 0.3 = 0.0075 \text{ mg P} \cdot \text{mg}^{-1} \text{ COD}$$

For the influent concentration of $S_{ii} = 1000 \text{ mg COD} \cdot \text{l}^{-1}$ the minimum required concentrations of nitrogen and phosphorus are calculated as:

$$N_l = 0.03 \cdot S_{ii} = 30 \text{ mg N} \cdot \text{l}^{-1}$$

$$P_l = 0.0075 \cdot S_{ii} = 7.5 \text{ mg P} \cdot \text{l}^{-1}$$

For the given nitrogen and phosphorus influent concentrations ($2 \text{ mg} \cdot \text{l}^{-1}$ of both N and P), the deficits are $30 - 2 = 28 \text{ mg N} \cdot \text{l}^{-1}$ and $7.5 - 2 = 5.5 \text{ mg P} \cdot \text{l}^{-1}$. The minimum dosage of DAP is calculated by considering that 1 mol DAP (128 g) has 2 moles of N (28 g) and 1 mol of P (31 g). Thus the addition of $1 \text{ mg} \cdot \text{l}^{-1}$ of DAP results in an increase of $28/128 = 0.21 \text{ mg N} \cdot \text{l}^{-1}$ and $31/128 = 0.23 \text{ mg P} \cdot \text{l}^{-1}$. Hence for the required $5.5 \text{ mg P} \cdot \text{l}^{-1}$ there is a demand of $5.5/0.23 = 24 \text{ mg DAP} \cdot \text{l}^{-1}$. For the demand of $28 \text{ mg N} \cdot \text{l}^{-1}$ the required DAP addition would be $28/0.21 = 133 \text{ mg DAP} \cdot \text{l}^{-1}$.

An alternative is to add the required concentration for the phosphorus demand (adding $24 \text{ mg} \cdot \text{l}^{-1}$ for $5.5 \text{ mg} \cdot \text{l}^{-1}$ of P and $0.21 \cdot 24 = 5.0 \text{ mg} \cdot \text{l}^{-1}$ of N) and supply urea to make up for the remaining nitrogen demand. Knowing that urea has a nitrogen fraction of $28/60 = 0.47 \text{ mg N} \cdot \text{mg}^{-1} \text{ urea}$, for the residual N demand of $28 - 5 = 23 \text{ mg N} \cdot \text{l}^{-1}$, addition of $23/0.47 = 49 \text{ mg} \cdot \text{l}^{-1}$ of urea is required. For the flow of $2000 \text{ m}^3 \cdot \text{d}^{-1}$, the nutrient demand is $2000 \cdot 0.024 = 48 \text{ kg} \cdot \text{d}^{-1}$ of DAP and $2000 \cdot 0.049 = 98 \text{ kg} \cdot \text{d}^{-1}$ of urea. The residual nutrient concentration would be zero.

In practice recycling the liquid phase of the sludge digester to the biological reactor could reduce the nutrient demand, as in the sludge digester part of the organic material is converted into biogas and the corresponding nutrients will be released as ammonium and phosphate.