Example 8.5

For an activated sludge process operating at a sludge age of 6 days and a temperature of 20℃ determine the following parameters for a system configuration with and without primary settling:

(a) COD fractions: (1) digested, (2) in the effluent, (3) oxidised and (4) in the stabilised sludge;
(b) The methane production per unit mass of applied COD;
(c) The ammonia concentration in the digester effluent.

To make the necessary calculations the following assumptions are made: $f_{ns} = f_{np} = 0.1$ for the raw sewage. In the case of primary settling, it is assumed that 80 percent of the particulate non-biodegradable material and 30 percent of the total influent COD will be removed.

Solution:

(a) Without primary settling

Calculate the active and inactive excess sludge production. The active excess sludge production is given by:

$$mE_{xa} = (1 - f_{ns} - f_{np})\cdot C_r/R_s = 0.8\cdot 0.45/(1 + 6\cdot 0.24) = 0.15 \text{ mg VSS.mg}^{-1} \text{ COD}$$

The production of volatile solids is calculated as:

$$mE_{xv} = mE_{xa}\cdot(1 + f\cdot b_h\cdot R_s) + f_{np}/f_{cv} = 0.26 \text{ mg VSS.mg}^{-1} \text{ COD}$$

Hence the production of inactive sludge is given by:

$$mE_{nxa} = mE_{xv} - mE_{xa} = 0.11 \text{ mg VSS. mg}^{-1} \text{ COD}$$

The fraction of the influent COD digested in the process is calculated from Eq. (8.61):

$$mS_d = 1.5\cdot(R_{dp}\cdot mE_{xa} + R_{dn}\cdot mE_{nxa}$$
$$=1.5\cdot(0.67\cdot 20 + 36)\cdot 0.15 + (0.19\cdot 20 + 10)\cdot 0.11)/100 = 0.093 \text{ mg COD.mg}^{-1} \text{ COD}$$

The influent COD fraction discharged into the effluent is equal to the non-biodegradable and soluble influent fraction, which is given as $f_{ns} = 0.10$. The oxidised influent COD fraction is calculated as:

$$mS_o = (1 - f_{ns} - f_{np})\cdot(1 - f_{cv}\cdot Y + f_{cv}\cdot b_h\cdot(1 - f)\cdot C_r) = 0.8\cdot(0.33 + 0.32) = 0.52$$

Finally the influent COD fraction discharged as stabilised sludge can be calculated as:

$$mS_x = 1.0 - mS_{te} - mS_o - mS_d = 1.0 - 0.1 - 0.52 - 0.09 = 0.29$$

The percentage of solids that is converted in the digester is given by:

$$R_{xv} = (mS_d/f_{cv})/mE_{xv} = (0.09/1.5)/0.26 = 0.23$$

This percentage can also be calculated by considering that the COD fraction discharged as biological excess sludge from the aeration tank is given by $mS_{xv} = 1 - 0.1 - 0.52 = 0.38$ so that the converted fraction is $mS_d/mS_{xv} = 0.09/0.38 = 0.23$. The methane production per unit mass of influent COD is calculated with the aid of Eq.(8.62):

$mM_e = mS_d/4 = 0.093/4 = 23$ g $CH_4.kg^{-1}$ COD

The ammonium production in the anaerobic digester can be estimated by using Eq. (8.67):

$$mN_{ld} = f_n \cdot (R_{dp} \cdot f_{av} \cdot mE_v + R_{dn} \cdot (1 - f_{av}) \cdot mE_v)$$
$$= 0.1 \cdot (0.52 \cdot 0.09 + 0.15 \cdot 0.11) = 6.3 \text{ g N.kg}^{-1} \text{ COD}$$

This ammonia production represents 5 to 10 percent of the influent TKN mass and must be taken into consideration when designing the activated sludge process for tertiary treatment (nitrogen removal).

(b) With primary settling

If a removal efficiency of 30 percent of the influent COD is assumed, the primary sludge production can be estimated as:

$mE_{v1} = 0.3/f_{cv} = 0.2$ g VSS.g^{-1} COD

In the raw sewage, the fractions of soluble and particulate organic material f_{ns} and f_{np} are equal to 0.10. As S_{nsi} is not settleable (dissolved matter) and 80 percent of S_{npi} and 30 percent of S_{ti} are removed during primary settling, the non-biodegradable fractions in the settled sewage are adapted after settling to:

$f'_{ns} = 0.1/0.7 = 0.143$ and $f'_{np} = 0.02/0.7 = 0.029$

The active sludge production is calculated as:

$mE_{xa} = 0.7 \cdot (1 - 0.143 - 0.029) \cdot C_r/R_s = 0.7 \cdot 0.83 \cdot 0.9375/6 = 0.11$ mg $X_a.mg^{-1}$ COD

The volatile biological sludge production is given by:

$mE_{xv} = mE_{xa} \cdot (1 + f \cdot b_h \cdot R_s) + f_{np}/f_{cv} = 0.14 + 0.029/1.5 = 0.17$

Therefore the inactive secondary sludge production is expressed as:

$mE_{nxa} = mE_{xv} - f_{av} \cdot mE_{xv} = 0.16 - 0.11 = 0.06$
The active fraction $f_{av} = (0.17 - 0.06)/0.17 = 0.65$

Now by using Eq. (8.61) one has:

$$mS_d = 1.5 \cdot (0.52 \cdot (mE_{v1} + f_{av} \cdot mE_{v2}) + 0.15 \cdot (1 - f_{av}) \cdot mE_{v2})$$
$$= 1.5 \cdot (0.52 \cdot 0.31 + 0.15 \cdot 0.05) = 0.25$$

The COD fraction in the effluent is not affected by primary settling so that:

$mS_{te} = f_{ns} = 0.1$

The oxidised fraction after primary settling is expressed as:

$$mS_o = 0.7 \cdot (1 - f_{ns} - f_{np}) \cdot (1 - f_{cv} \cdot Y + f_{cv} \cdot b_h \cdot (1 - f) \cdot C_r)$$
$$= 0.7 \cdot 0.83 \cdot (0.33 + 0.32) = 0.36$$

The COD fraction discharged as stabilised sludge is:

$mS_x = 1 - mS_{te} - mS_o - S_d = 1 - 0.1 - 0.36 - 0.25 = 0.29$

The methane production is determined as in Eq. (8.62):

$mMe = mS_d/4 = 0.25/4 = 62$ g $CH_4.kg^{-1}$ COD

The ammonia production in the digester is estimated as in Eq. (8.66):

$$mM_{ld} = f_n \cdot (R_{dp} \cdot mE_{xa} + R_{dn} \cdot E_{xna})$$
$$= 0.1 \cdot (0.52 \cdot 0.11 + 0.15 \cdot 0.05) = 6.5 \text{ g N.kg}^{-1} \text{ COD}$$

The percentage of solids removal in the digester is now given by:

$$R_{xv} = (mS_d/f_{cv})/(mE_{v1} + mE_{v2}) = (0.25/1.5)/(0.16 + 0.2) = 0.46$$

Fig. 8.17 graphically shows the division of the four COD fractions over (1) the effluent, (2) oxidised sludge, (3) digested sludge, and (4) the stabilised sludge, both for the case of primary settling and for raw sewage treatment. It can be noted that a considerable part of the removed organic material is degraded via the anaerobic pathway, especially if primary settling is applied.

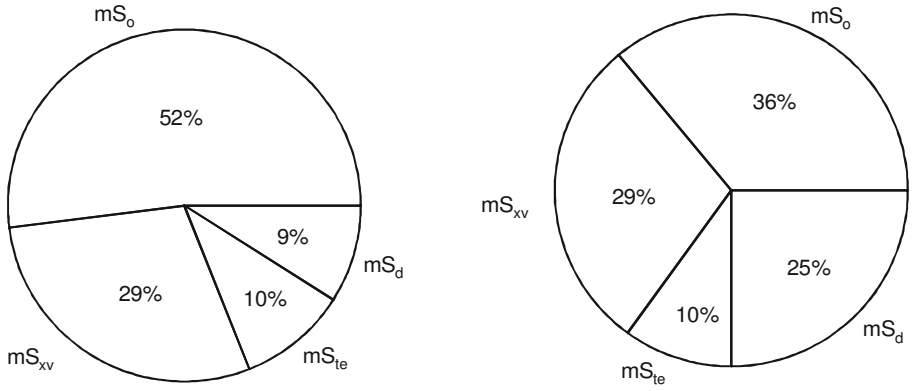

Figure 8.17 Division of the influent COD over fractions mS_e, mS_o, mS_{xv} and mS_d in Example 8.3, without (left) and with primary settling (right)