3.2.4.3 Sludge production and nutrient demand

The sludge production can be calculated directly from the sludge mass in the activated sludge system. Knowing that the sludge production is a fraction $1/R_s$ of the existing sludge mass, one has:

$$mE_v = mX_v/R_s = (1 - f_{ns} - f_{np})\cdot(1 + f\cdot b_h\cdot R_s)\cdot C_r/R_s + f_{np}/f_{cv} \quad (3.58)$$

Where:

mE_v = volatile sludge mass produced per unit mass applied COD (mg VSS.mg^{-1} COD)

Fig 3.10 shows the sludge production as a function of the sludge age for $f_{ns} = f_{np} = 0.10$ (raw sewage) as well as $f_{ns} = 0.10$ and $f_{np} = 0.02$ (settled sewage). Along with carbon, volatile sludge is composed of several elements, of which nitrogen and phosphorus are the most important ones. The nitrogen fraction of volatile sludge is 10 percent of the sludge mass. As for phosphorus, its mass fraction is about 2.5 percent both for active and inactive volatile sludge in completely aerobic systems. If part of the activated sludge system is operated under anaerobic (non-aerated) conditions, this fraction can increase to a maximum of 38 percent. (Wentzel et al, 1991). The conditions for producing active sludge with a high phosphorus content for biological phosphorus removal are discussed in Chapter 5.

To compensate for nutrient losses in the excess sludge, the waste water must supply the activated sludge with new nutrients. If insufficient nutrients are present in the influent, the activated sludge system will not function properly: e.g. problems with bulking sludge may appear. The required influent nutrient concentrations required for excess sludge production can be calculated by equating the minimum influent flux to the nutrient flux in the excess sludge. For nitrogen one has:

$$mN_l = f_n\cdot mE_v \quad (3.59)$$

Where:

mN_l = mass of nitrogen needed for sludge production per unit mass daily applied COD
f_n = mass fraction of nitrogen in volatile sludge = 0.1 g N.g^{-1} VSS

For phosphorus the corresponding expression is:

$$mP_l = f_p\cdot mE_v \quad (3.60)$$

Where:

mP_l = phosphorus mass required for sludge production per unit mass of daily applied COD
f_p = fraction of phosphorus in sludge = 0.025 g P.g^{-1} VSS.

As an example in Fig. 3.10 the values of mN_l and mP_l have been plotted as a function of sludge age.

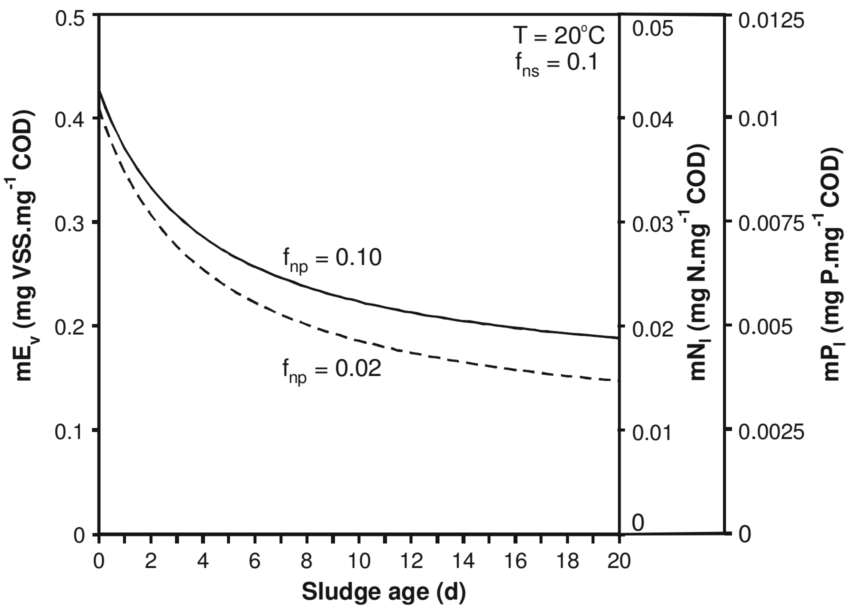

Figure 3.10 Typical profile of volatile sludge production and nitrogen / phosphorus demand as function of the sludge age for raw (f_{np} = 0.10) and settled sewage (f_{np} = 0.02)

Once the values of mN_l and mP_l have been established, it is a simple matter to calculate the corresponding minimum required nutrient concentrations in the influent. For nitrogen one has:

$mN_l = MN_l/MS_{ti} = (Q_i \cdot N_l)/(Q_i \cdot S_{ti}) = N_l/S_{ti}$ or

$$N_l = mN_l \cdot S_{ti} = f_n \cdot mE_v \cdot S_{ti} = f_n \cdot [(1 - f_{ns} - f_{np}) \cdot [(1 + f \cdot b_h \cdot R_s) \cdot C_r/R_s + f_{np}/f_{cv}] \cdot S_{ti} \quad (3.61)$$

For phosphorus one calculates:

$mP_l = MP_l/MS_{ti} = (Q_i \cdot P_l)/(Q_i \cdot S_{ti}) = P_l/S_{ti}$ or

$$P_l = mP_l \cdot S_{ti} = f_p \cdot mE_v \cdot S_{ti} = f_p \cdot [(1-f_{ns}-f_{np}) \cdot [(1+f \cdot b_h \cdot R_s) \cdot C_r/R_s + f_{np}/f_{cv}] \cdot S_{ti} \quad (3.62)$$

Where:

N_l = influent nitrogen concentration required for excess sludge production
P_l = influent phosphorus concentration required for excess sludge production

In the case of domestic waste water, the concentrations of the nutrients will be much higher than the minimum values required for sludge production. However, in industrial waste waters, especially those of vegetable origin, the nutrient concentrations are low and additions to the influent may be necessary to have a properly functioning system.