8.3.5 Potential of energy generation in anaerobic sludge digesters

The potential for energy production during anaerobic digestion in the form of methane is of significant practical importance. It is interesting to compare the energy production potential to the energy demand for aeration.

For most aerators operating under process conditions, the required energy for aeration is in the order of 1 $kWh.kg^{-1}$ O_2 transferred (Section 3.3). The oxygen demand depends on the influent composition (COD and nitrogen amount and -composition) and the sludge age. These factors determine the fraction of influent COD that will be oxidised in the activated sludge process and whether nitrification will take place. For a nitrifying activated sludge process one has:

$$MO_t = MO_c + MO_n - MO_{eq}$$

If nitrification and (therefore) denitrification does not take place, the energy demand can be linked directly to the oxidised COD fraction:

$$mS_o = (1 - f_{ns} - f_{np})\cdot(1 - f_{cv}\cdot Y + f_{cv}\cdot(1 - f)\cdot C_r)$$

The chemical energy in the produced methane can be determined from the combustion heat: 12,000 kCal or 50,400 $kJ.kg^{-1}$ CH_4. However, when methane is used for electrical power generation not all the available chemical energy is converted into electrical energy: typically the energy conversion efficiency is in the order of only 30 to 35 percent in conventional generators (explosion motors), or up to 50 percent in modern units (turbines). Assuming an energy conversion efficiency of R_{el}, the electrical power production potential can be estimated as:

$$P_{el} = R_{el}\cdot 50{,}400 \text{ kJ.kg}^{-1} \text{ CH}_4$$
$$= R_{el}\cdot 50{,}400/3600 = R_{el}\cdot 14 \text{ kWh.kg}^{-1} \text{ CH}_4 \quad (8.67)$$

Knowing that l kg CH_4 originates from the digestion of 4 kg of COD or 4/1.5 = 2.677 kg VSS, the power production potential can be expressed as:

$$mP_{el} = \eta_{el}\cdot 14/2.677\cdot mE_d = \eta_{el}\cdot 5.25\cdot mE_d \quad (8.68)$$

Where:

P_{el} = electrical power production potential
η_{el} = energy conversion efficiency (30 to 35 percent)
mP_{el} = energy production potential per kg applied COD
mE_d = digested sludge mass per unit mass applied COD

From the results of Example 8.6, it is clear that the potential for energy production represents a significant fraction of the energy demand at an activated sludge plant. In the case of Example 8.6, the energy that could be produced varies between 107/520 = 21% (no primary settling) and 289/360 = 80% (with primary settling) of the energy demand. If a shorter sludge age is applied and more efficient energy conversion techniques (gas turbines) are used, it is possible to operate the activated sludge process without external energy consumption at all: the chemical energy of the influent organic matter would then be sufficient to supply the energy requirements of the system.

Thus there is a very large advantage in the anaerobic digestion process when compared with aerobic digestion. This is particularly so if there is no need to heat the reactor contents of the anaerobic reactor, as will be the case in tropical and subtropical regions. Under those circumstances, the energy consumption in a process with aerobic digestion can easily be more than twice the demand when anaerobic digestion is applied. It is concluded that anaerobic digestion will reduce the operational costs of activated sludge processes and should always be applied, unless it is technically impossible, as may be the case when industrial waste waters with toxic components are treated.