8.3.2 Configurations used for anaerobic digestion

The classical or low rate anaerobic digester is presented schematically in Fig. 8.13. In this digester there is a vertical stratification and the following layers can be distinguished from top to bottom:

- Scum layer composed of non-biodegradable or slowly biodegradable material (like leaves, hair, rags, plastic etc.) floating on the liquid phase. When the temperature is very low, this layer may become tough and obstruct the release of the produced biogas;
- Supernatant of a liquid phase with a relatively low solids concentration that is established as a result of sedimentation processes;
- Active digestion zone, the part of the anaerobic digester where the actual conversion of organic matter into biogas takes place;
- Stabilised sludge zone: the part of the digester in which the digested sludge accumulates and from where it is discharged for additional treatment or final disposal.

It can be noted that the digester performs two simultaneous functions at the same time: sludge stabilisation by anaerobic digestion and separation of the digested solids from a supernatant substantially free of suspended solids. In practice the digester will not be very efficient, because the two functions are carried out in the same reactor while the optimal operational conditions for both are very different: for efficient digestion intense mixing is required, to ensure that good contact is established between the anaerobic biomass and the excess sludge. The mixing may be enhanced by recirculation of the produced biogas or by mechanical mixers. In contrast, a condition for efficient settling is a tranquil environment.

As the digester is not very efficient in either digestion or phase separation, a large volume is required to obtain a properly stabilised sludge. The long retention time compensates for the inherent inefficiency of the low rate digestion concept. In the 1950s, the high rate anaerobic digester was developed in which the entire volume of the digester is effectively used for digestion and phase separation is carried out in a separate unit specifically constructed for this purpose.

Usually the second unit is constructed as a secondary digester with reference to the two "digesters" in series, but this denomination is not very appropriate, because the two stages of anaerobic digestion (acid and methanogenic fermentation) will occur mainly in the first digester, with a possibility of some activity in the second one.

Apart from phase separation, the secondary digester carries out a second function as a storage tank for digested sludge. The accumulated methanogenic sludge may be recirculated to the primary digester when this is convenient, for example, when there are signs of imminent souring. Furthermore, the secondary digester can be used as a single digester if the primary digester needs to be taken out of operation for maintenance. Thus the presence of the secondary digester improves the flexibility and operational stability of the anaerobic digestion process of excess sludge.

However, even in the secondary digester, the liquid-solid separation efficiency may not be satisfactory as the digested sludge tends to float due to the adsorption of flocs to biogas bubbles that rise to the liquid surface and because often a considerable part of the solids in the digested sludge may have very poor settling properties.

Recycling of the supernatant with a high concentration of suspended solids and other materials (nutrients) represents an extra load for the sludge in the aeration tank. For this reason, there is a tendency to substitute the secondary digester by a specific liquid-solid separator. Since it may be assumed that the phase separation in such a unit will be better than in the secondary digester, it is to be expected that the recycling of the supernatant will cause less problems.

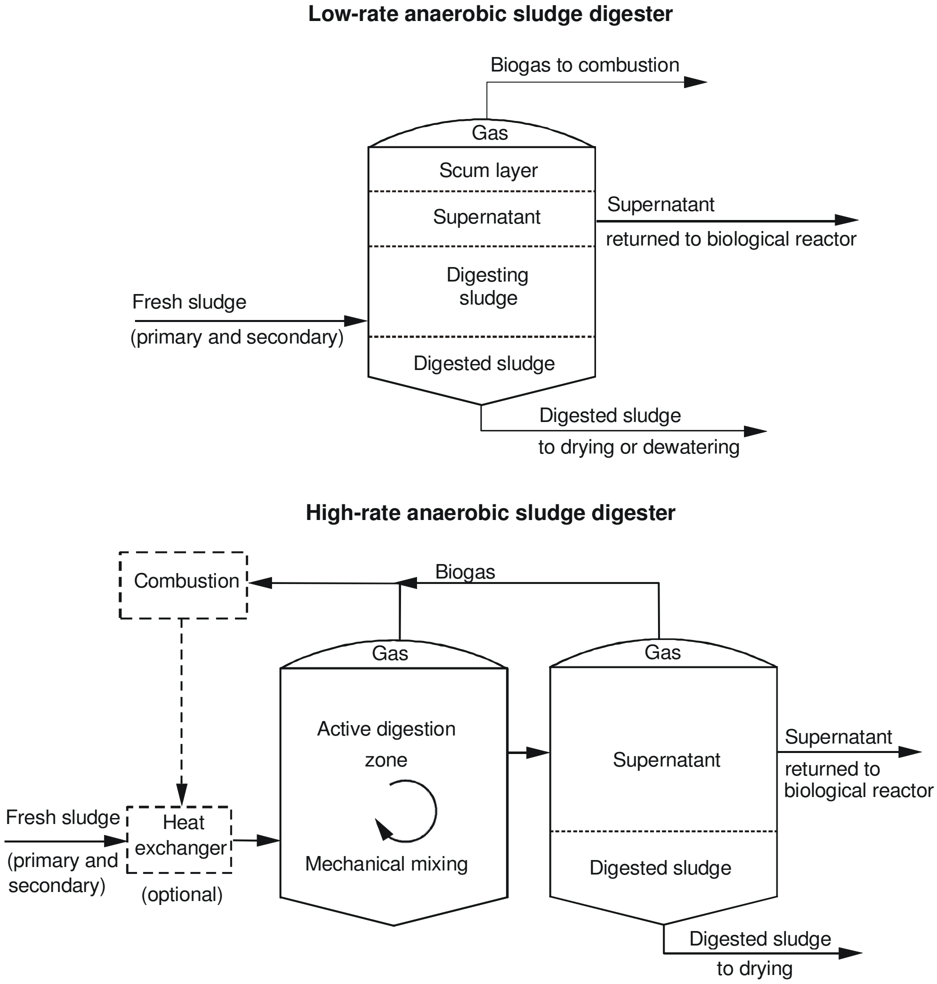

Figure 8.13 Basic configurations of low (upper figure) and high (lower figure) rate anaerobic sludge digesters

The performance of the high rate digester may be stimulated by several measures.

(a) Continuous feeding

Continuous or semi-continuous introduction of the excess sludge favours the stable performance of the digester. Intermittent feeding with a frequency of once per day or less leads to large fluctuations in the composition and concentration of the substrate and may result in a tendency for souring.

(b) Mixing of the primary reactor contents

Mixing favours a homogeneous composition of the mixed liquor in the digester and improves the contact between the anaerobic biomass and the excess sludge to be digested. In addition, possible toxic compounds are quickly diluted over the whole reactor volume, reducing the possibility of disruption of the fermentation equilibrium.

Furthermore the formation of a scum layer is avoided, thus preventing the danger of serious operational problems. Common methods for mixing are (1) pumping of mixed liquor with an external pump, often combined with external heat exchange, (2) internal mechanical mixers, and (3) mixing by recycling of the produced biogas.

(c) Thickening and recycling of digested sludge

Tarp and Melbinger (1967) showed the large advantages of recycling digested sludge and mixing it with excess sludge. The mixture can be concentrated to a much higher solids content than would be possible for the excess sludge alone. There is an upper limit to the suspended solids concentration in the digester: at a concentration above 8 to 10 percent of suspended solids, the mixing of the digester contents becomes difficult due to the high viscosity of the mixed liquor. Furthermore the concentration of mineralised materials (ammonium, alkalinity) may reach such high values that toxicity becomes a problem, although methanogenic bacteria are able to adapt to very high ammonium concentrations: 2500 $mg.l^{-1}$ has been demonstrated by Rinzema (1989).

(d) Heating

The metabolic activity of the bacteria in the anaerobic digestion process increases up to the optimal temperature of 35 to 37°C. When heating of the anaerobic digester is applied, the produced methane is usually used as a fuel. Internal or external heat exchangers may be used. The decision as to whether heating of the digester is attractive, depends predominantly on the minimum environmental temperature. If it has a low value, a considerable increase in sludge activity can be expected when heating is applied and consequently the required digester volume will be much smaller. On the other hand, the equipment required to maintain a high and constant temperature is expensive and skilled labour is required to operate the digester. Hence heating is only attractive at low temperatures if proper performance without it is impossible. In tropical and subtropical regions, the environmental temperature in general is sufficiently high to avoid heating of the digester.