3.1.2 The composition of organic sludge

The sludge in the activated sludge system is composed of the suspended solids in the mixed liquor (the contents of the biological reactor or aeration tank). The sludge concentration can be determined experimentally: the sludge is filtered and weighed after drying at 103 °C, thus obtaining the total suspended solids concentration (TSS). The TSS can be divided into organic and inorganic solids.

The inorganic sludge is generated by flocculation of inorganic influent material such as clay, silt and sand and by precipitation of salts during the biological treatment. In sludge from municipal waste waters, the inorganic sludge fraction is in the order of 20 to 35% of the total sludge concentration. Its concentration can be determined experimentally by measuring the total solids after ignition at 550°C, a temperature that results in the complete combustion of the organic solids.

The organic solids concentration is calculated from the weight loss during the ignition. Due to the fact that the organic solids disappear during the ignition, these are also called volatile suspended solids (VSS), distinguishing them from the remaining, fixed suspended solids (FSS).

In order to describe the activated sludge behaviour, Marais and Ekama (1976) suggested a subdivision of the volatile suspended solids in two basic fractions: (1) active sludge, composed of the living micro-organisms that act in the metabolism of the influent organic material and (2) inactive sludge composed of organic material that does not exhibit metabolic activity. It is important to stress, that this division is theoretical and that there is no test to directly determine the active or inactive sludge concentration: only the sum of the two can be determined experimentally. The division is justified by the fact that it leads to a rational model of the activated sludge system, capable of predicting the measurable parameters under strongly varying operational conditions.

3.1.2.1 Active sludge

The active sludge is generated from synthesis of influent organic material. The micro-organisms in the activated sludge system are composed of a very large number of species of bacteria, fungi and protozoa. Depending on the operational conditions, more complex organisms like ciliates and rotifers may also be present.

The composition of the active sludge may differ considerably from one system to the other, depending on the nature of the influent waste water and the operational conditions. In spite of the complex nature of the active sludge mass, in this text it will be considered (for the purpose of modelling) as an equivalent bacterial suspension. To test the validity of this assumption, the predictions generated by the model will be compared to the experimentally observed results. It must be stressed that although bacteria are predominant in the active sludge, its actual behaviour may be very different from a pure culture of bacteria.

3.1.2.2 Inactive sludge

The inactive sludge is composed of non biodegradable organic material and can be subdivided in two fractions in accordance with its origin: (1) the inert sludge and (2) the endogenous residue. The inert sludge fraction is generated from the accumulation of particulate non-biodegradable organic material present in the influent. This material is flocculated and becomes part of the solid phase, forming the inert fraction.

The endogenous residue has its origin in the decay of living bacteria cells, a process occurring continuously in the activated sludge system. During the decay process of the active sludge, part of the microbial mass is oxidised in a process called endogenous respiration.

However, only part of the cellular mass is biodegradable: after decay a fraction of the decayed active sludge remains in the activated sludge as a non-biodegradable particulate fraction. The existence of the endogenous residue will be demonstrated and quantified in Chapter 8.

Apart from the different organic fractions of the sludge there is also an inorganic one. This material can be determined after the organic material is removed by means of ignition at 550°C. It should be noted that part of the measured weight is due to the formation of phosphates, sulphates and bicarbonates during the combustion of the organic material. Experimentally the value of the formed inorganic residue of the organic sludge has been determined as approximately 20%. This means that the measured volatile sludge mass (active, inert and endogenous) is accompanied by a fixed solids mass fraction of 1/0.8 -1 = 25%.

In addition to the inorganic fraction formed after ignition of the volatile sludge, there may be inorganic solids in the sludge originating from material in the influent such as silt and clay. Thus in practice the ratio between volatile and total suspended solids tends to be less than 0.80. Depending on the origin of the waste water and the operational conditions (pre-sedimentation, applied sludge age, quality of the sewer system), the ratio between volatile and total solids for domestic sewage will be in the order of 0.65 to 0.75. For industrial waste waters containing a very low or even no inorganic material, this ratio will be close to the observed maximum of 0.80.

3.1.2.3 Definition of sludge fractions

Having defined the different sludge fractions, it is convenient to introduce symbols for each. Using the letter "X" to indicate generically sludge concentration one has:

X_a = active sludge concentration (mg VSS.l^{-1})

X_e = endogenous sludge concentration (mg VSS.l^{-1})

X_i = inert sludge concentration (mg VSS.l^{-1})

X_v = organic or volatile sludge concentration (mg VSS.l^{-1})

X_m = mineral, fixed or inorganic sludge concentration (mg FSS.l^{-1})

X_t = sludge concentration (mg TSS.l^{-1})

From the definitions it follows that:

$$X_v = X_a + X_e + X_i \quad (3.4)$$

$$X_t = X_v + X_m = X_v/f_v \quad (3.5)$$

Where f_v is the volatile sludge fraction:

= 0.65 - 0.75 (raw sewage)
= 0.70 - 0.80 (pre-settled sewage)
= 0.80 (waste waters without mineral suspended solids)

Along with the three organic sludge fractions defined above, another two may exist, depending on the operational conditions. If the sludge age is very short, the sludge wastage rate may be so high that there is not enough time for the metabolisation of all the influent biodegradable material especially at low temperatures. In that case flocculation of the particulate biodegradable organic material in the influent will occur and this material will be adsorbed (stored) on the active sludge mass. Thus it is possible that part of the discharged organic sludge is actually flocculated influent organic material.

The stored material fraction depends on the rate of metabolisation, the sludge age and of course, on the composition of the influent organic material.

If nitrification takes place in the activated sludge system, a population of nitrifying bacteria (Nitrobacter and Nitrosomonas) will develop. In the case of municipal sewage, the mass of nitrifying bacteria is very small compared to the total organic sludge mass (Chapter 4). In case of systems designed for biological phosphorus removal, a specific biomass will develop (phosphate accumulating organisms or PAO), with an increased phosphorus content of up to 38% (Chapter 5). Naturally, in this case the proportion between volatile sludge and total sludge will be lower.