

### 4.2.2 Operational factors influencing nitrification

In so far as operational conditions are concerned, the following factors have been shown to influence nitrification and particularly the  $\mu_m$  value: temperature, dissolved oxygen concentration and pH.

#### (a) Temperature

There is a strong influence of temperature on the  $\mu_m$  value as the experimental results obtained by several authors show. Often a simplified Arrhenius equation is used to describe the influence of temperature, i.e.:

$$\mu_{mT} = \mu_{m20} \cdot \theta^{(T-20)} \quad (4.33a)$$

Where  $\theta$  = Arrhenius temperature dependency coefficient

Table 4.3 shows the experimental results of some authors. The  $\theta$  value ranges from 1.11 to 1.13; which means that the  $\mu_m$  value increases by 11 to 13 percent per °C of temperature increase. Hence, the  $\mu_m$  value doubles for every 6 to 7°C of temperature increase.

**Table 4.3 Temperature dependency of the maximum specific growth rate of Nitrosomonas**

Temp. factor ( $\theta$ )	Temperature interval (°C)	Reference
1.116	19 - 21	Gujer (1977)
1.123	15 - 20	Downing et al (1964)
1.123	14 - 20	Ekama et al (1976)
1.130	20 - 30	Lijklema(1973)

The influence of the temperature on the growth rate of the nitrifiers has an important repercussion on the activated sludge process. In regions with a moderate climate, waste water temperatures in winter are in the range of 8 to 14°C, resulting in a low value of  $\mu_m$ . For a medium value of  $\mu_m$  of 0.4 d<sup>-1</sup> at 20°C, one would expect values 0.2 d<sup>-1</sup> at 14°C and 0.1 d<sup>-1</sup> at 8°C. From Eq. (4.32), it is calculated that the minimum sludge age for nitrification in this case will be in the range of 6 to 14 days. Therefore in Europe, it is common that activated sludge processes for nutrient removal are operated at a sludge age of more than 15 days.

In contrast, in tropical regions water and sewage temperatures are high. For example, in Campina Grande in North East Brazil (a.k.a. the Queen of the Borborema Heights), the average temperature is 26°C during summer. If again it is assumed that  $\mu_m = 0.4$  d<sup>-1</sup> at 20°C, the  $\mu_m$  value at sewage temperature is calculated as  $\mu_m = 0.8$  d<sup>-1</sup> at 26°C so that the minimum sludge age for nitrification is now only  $R_{sn} = 1.25$  days. In practice, the activated sludge process will be almost invariably operated at a longer sludge age, so that nitrification will develop if enough oxygenation capacity is available.

#### (b) Dissolved oxygen concentration

The influence of the dissolved oxygen concentration on nitrification kinetics has been the object of several studies. Several authors have proposed a Monod type equation to incorporate the influence of the dissolved oxygen concentration (Stenstrom and Poduska, 1980). In the IWA models no. 1 and 2, this approach has also been followed. Both ammonium and dissolved oxygen are considered substrates and the maximum specific growth rate is expressed as:

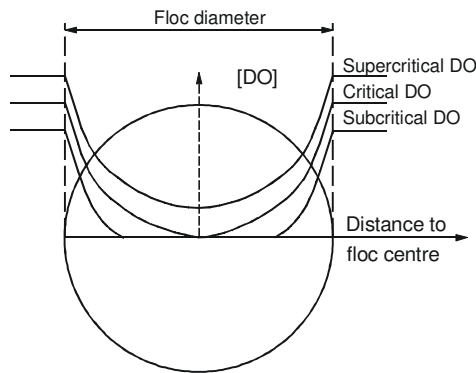
$$\mu = \mu_m \cdot N_a / (N_a + K_n) \cdot DO / (DO + K_o) \tag{4.34}$$

Where:

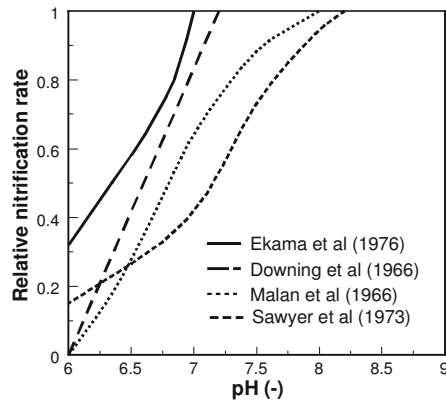
DO = dissolved oxygen concentration (mg O<sub>2</sub>.l<sup>-1</sup>)

K<sub>o</sub> = half saturation constant (mg O<sub>2</sub>.l<sup>-1</sup>)

The value attributed to K<sub>o</sub> varies considerably between different authors and values ranging from 0.3 to 2.0 mg O<sub>2</sub>.l<sup>-1</sup> have been published. This wide range may be due to the fact that it is only possible to determine the dissolved oxygen concentration in the bulk of the liquid phases. In the sludge flocs, where consumption occurs, the dissolved oxygen concentration is lower than in the bulk. The oxygen consumption creates a concentration gradient from the floc surface (where the dissolved oxygen concentration is considered to be equal to the bulk concentration) to the centre. Fig. 4.7 schematically shows the dissolved oxygen concentration profile in a sludge floc as a function of the distance to its centre (a spherical floc is assumed).



**Figure 4.7**  
Dissolved oxygen (DO) concentration gradient as a function of distance from the floc surface



**Figure 4.8**  
Influence of the pH on the nitrification rate according to EPA (1976)

Depending on the existing bulk dissolved oxygen concentration and the rates of dissolved oxygen transport and -consumption within the floc, anoxic micro regions may develop in the floc centre, where no dissolved oxygen is present and where, as a consequence, no nitrification will take place. Instead denitrification may develop.

This phenomenon is called simultaneous denitrification and is often observed in circulation systems such as the carousel, which essentially is a completely mixed system (for all components except oxygen) in which the mixed liquor is subjected to an oxygen gradient over the length of the reactor. The minimum bulk dissolved oxygen concentration that is required to maintain the centre of the flocs in an aerobic state depends on several factors such as floc size, stirring intensity, temperature and the oxygen uptake rate. As these factors may differ significantly between different active sludge processes, the required minimum dissolved oxygen concentration will vary as well. In general a bulk dissolved oxygen concentration of 2 mg O<sub>2</sub>.l<sup>-1</sup> should be sufficient to prevent oxygen limitation in the nitrification process.

**(c) Mixed liquor pH**

Several authors have found approximately constant  $\mu_m$  values over pH range from 7 to 8.5. For pH values below this range, the value of  $\mu_m$  decreases rapidly, as shown in Fig. 4.8. In practice, many waste waters (e.g. municipal waste water) have a pH value between 7 and 8. In the activated sludge process this value tends to decrease, because of the consumption of alkalinity due to nitrification and an increase of acidity due to the production of  $\text{CO}_2$  from the oxidation of organic matter. For this reason, unless the influent contains a high alkalinity, the mixed liquor pH will be less than 8. Hence, only the pH lower limit of mixed liquor is of practical importance. As discussed earlier, a pH below 7 can be avoided by maintaining the alkalinity above a minimum value of 35 ppm  $\text{CaCO}_3$ .