2.3.2 Anoxic respiration

Until now it was assumed that the organic material is metabolised in an aerobic environment, i.e. in the presence of oxygen. However, oxygen may not be available to the micro-organisms and in that case other compounds may serve as an alternative oxidant. In waste water treatment plants nitrate (NO_3^-), nitrite (NO_2^-) and sulphate (SO_4^{2-}) are possible substitutes for oxygen. Most bacteria in activated sludge can use nitrate or nitrite if no oxygen is available (facultative bacteria). In contrast, sulphate reducers are micro-organisms that cannot survive in an aerobic environment. The half reactions of the oxidants can be written as:

Oxygen: $e^- + H^+ + {}^1/_4\ O \rightarrow {}^1/_2\ H_2O$ (2.9a)

Nitrate: $e^- + {}^6/_5\ H^+ + {}^1/_5\ NO_3^- \rightarrow {}^1/_{10}\ N_2 + {}^3/_5\ H_2O$ (2.9b)

Nitrite: $e^- + {}^4/_3\ H^+ + {}^1/_3\ NO_2^- \rightarrow {}^1/_6\ N_2 + {}^2/_3\ H_2O$ (2.9c)

Sulphate: $e^- + H^+ + {}^1/_8\ SO_4^{2-} \rightarrow S^{2-} + {}^1/_2\ H_2O$ (2.9d)

The equations show the equivalence between ${}^1/_4$ mol O_2 (= 8 g O_2), ${}^1/_5$ mol NO_3^- (14/5 = 2.8 g N) and ${}^1/_8$ mol SO_4^{2-} (= 4 g S). Hence stoichiometrically 1 g NO_3-N is equivalent to 8/2.8 = 2.86 g O_2 and l g SO_4-S is equivalent to 8/4 = 2.00 g O_2.

Example 2.6

If sulphite is used by bacteria, reducing it to sulphide, how many grams of COD can be oxidised per g of SO_3^{2-}-S ?

Solution:

The half equation for sulphite is:

$e^- + H^+ + {}^1/_6\ SO_3^{2-} \rightarrow {}^1/_6\ S^{2-} + {}^1/_2\ H_2O$ (2.9e)

Hence, ${}^1/_6$ mol of sulphite (32/6 = 5.33 g S) is equivalent to ${}^1/_4$ mol of O_2, so that it can oxidise 8 g of COD. Hence, the oxidation of 1 g of COD requires 5.33/8 = 0.67 g SO_3-S. Stated differently, it takes 8/5.33 = 1.50 g COD to reduce 1 g of SO_3-S.

In the activated sludge process the reduction of nitrate to molecular nitrogen is called denitrification. This is a process of great importance in waste water treatment, as it is required for the biological removal of nitrogen from waste water. Nitrite is an intermediate in the nitrification process ($NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$), but as the oxidation of nitrite to nitrate proceeds (in general) faster than that of ammonium to nitrite, its concentration is very low under normal circumstances.

The reduction of sulphate generates hydrogen sulphide gas with its characteristic bad odour. This normally does not take place in the activated sludge process, but the process may develop under anaerobic conditions, for example in an excess sludge digester or in pre-treatment units such as primary clarifiers and sand traps.