

Introduction

In an activated sludge plant designed for tertiary treatment, the objective is to remove nutrients, suspended solids and organic matter. During the last few decades, the importance of nutrient removal has increased as a result of the necessity to avoid eutrophication of water bodies receiving untreated waste water and the effluent of waste water treatment plants. For this reason, many new waste water treatment plants are now designed for tertiary treatment.

Apart from the important repercussions on the effluent quality, tertiary treatment also has a beneficial influence on the performance of the waste water treatment process itself. This is particularly noticeable in the case of nitrogen removal. The development of nitrification in an activated sludge process is practically unavoidable when the sewage reaches temperatures of 22 to 24°C, which will be the case for at least part of the year in tropical and subtropical regions. The formed nitrate can be used by most micro-organisms in the activated sludge as a substitute to dissolved oxygen. In an anoxic environment, characterised by the presence of nitrate and the absence of dissolved oxygen, the nitrate ion can be reduced by organic matter to nitrogen gas: this process is called denitrification.

If the biological reactor is kept completely aerobic, the nitrified mixed liquor will flow to the settler, where an adequate environment is established for denitrification as soon as the oxygen is consumed; this will take only a few minutes. As a result of the development of denitrification in the settler, nitrogen bubbles will be formed and these will rise to the liquid surface. While rising, the bubbles may attach to sludge flocs, causing the flocs to be lifted to the liquid surface. Thus a floating layer will be formed, composed of sludge with attached nitrogen bubbles. Some of the nitrogen gas will escape, but enough will remain in the layer to keep it floating, which will eventually lead to sludge loss due to unintentional discharge with the effluent. Of course, the presence of sludge in the effluent will lead to unacceptable high concentrations of suspended solids and organic matter.

Another negative aspect of floating layers of denitrifying sludge and the discharge of sludge with the effluent refers to the operational stability of the activated sludge process. The sludge loss reduces the sludge age and sludge mass in the system. The remaining sludge mass may be insufficient to metabolise the influent organic matter, resulting in a reduction of secondary treatment efficiency. Furthermore the reduction of the sludge age may lead to wash out of the nitrifiers and hence interruption of the nitrification process. If no nitrate is produced, denitrification ceases as well and the problem of floating sludge will disappear. Thus favourable conditions are established for a recuperation of the secondary treatment efficiency. First, the fast growing heterotrophs will be re-established and efficient organic matter removal will be resumed. Subsequently the slower growing nitrifiers will also return in the sludge mass in sufficient quantities to nitrify the applied ammonium load. Nitrate will be formed and a new cycle of operational instability will be initiated.

In contrast, when nitrification and denitrification are controlled and occur as planned in the activated sludge process itself, before the mixed liquor reaches the final settler, this unit will behave as a normal liquid-solid separator. This allows an effluent containing very low concentrations of suspended solids, organic matter and nitrogen to be produced.

Nitrogen removal also has important economic consequences. In the nitrification process both oxygen and alkalinity are consumed, while in the denitrification process part of this consumption may be recovered. In the case of municipal sewage, the oxygen demand for nitrification is about $\frac{1}{3}$ rd of the total demand.

From stoichiometrics, it can be calculated that $\frac{5}{8}$ or 62 percent of the oxygen demand for nitrification may be recovered in the denitrification process. Thus in activated sludge processes with complete biological nitrogen removal (nitrification + denitrification), oxygen consumption will be $\frac{5}{8} \cdot \frac{1}{3} = \frac{5}{24}$ or about 20 percent lower than in comparable processes with nitrification only. Since aeration is the main part of the operational costs in an activated sludge process, a reduction of 20 percent of the oxygen demand is very significant in economic terms.

The alkalinity consumption by nitrification may result in a reduction of pH. The magnitude of this reduction depends on the initial alkalinity and the oxidised ammonium concentration. In many cases the pH tends to become unacceptably low and alkalinity addition (for instance in the form of lime: $\text{Ca}(\text{OH})_2$) will be necessary. During denitrification, half of the alkalinity consumption for nitrification is recovered. Thus the alkalinity demand is smaller and in many cases after the introduction of denitrification, addition of alkalinity is no longer necessary.