External nitrification in biological nutrient removal activated sludge systems

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Abstract

A biological nutrient removal (BNR) activated sludge (AS) scheme incorporating external nitrification in a fixed media system is proposed. A laboratory-scale evaluation of the scheme indicates that it holds considerable potential for BNRAS system intensification through major reduction in sludge age and oxygen demand and significant improvement in sludge settleability. Because the BNRAS system is not required to nitrify, its anoxic mass fraction can be considerably enlarged at the expense of the aerobic mass fraction creating conditions that allow it to achieve high N removals with domestic wastewaters with high TKN/COD ratios; and promote anoxic P uptake polyphosphate accumulating organisms (PAO) to develop in the system. From this, and earlier investigations with conventional nitrification denitrification biological excess P removal (NDBEPR) systems, it appears that anoxic P uptake BEPR is only about $^2/_3$ of aerobic P uptake BEPR. Hence, inclusion of aerobic P uptake PAOs in the BNRAS system is desirable for the proposed scheme. However, conditions that promote aerobic P uptake to maximise BEPR, are also conducive to nitrifier growth, which, if supported in the BNRAS system, would require virtual complete nitrification in the fixed media system to avoid nitrate interference with BEPR. Before the scheme can be implemented at large scale, an engineering and economic evaluation is required to quantify its potential benefits and savings.

Introduction: The long sludge age requirement for nitrification

The requirement to nitrify governs the sludge age of the biological nutrient removal activated sludge (BNRAS) system. For maximum specific growth rates of nitrifiers at 20°C (μ_{nm20}) around 0.45/d, to guarantee nitrification, the sludge age of the single sludge system must be around 20 to 25 d at 14°C, if 40 to 50% of the sludge mass in the system is aerated. Such long sludge ages result in large biological reactors per Mℓ wastewater (WW) treated. To reduce the sludge age, and hence the biological reactor volume per Mℓ WW treated, internal fixed media such as Ringlace™ have been placed in the aerobic reactor (Wanner et al., 1988; Sen et al., 1994, 1995; Randall and Sen, 1996). The nitrifiers grow on the fixed media establishing a population permanently resident in the aerobic reactor. These nitrifiers are not subject to either the aerobic sludge mass fraction or the suspended mixed liquor sludge age, with the result that both can be reduced. Such a reduction in system sludge age is particularly beneficial for low temperature WWs (10 to 15°C). However, the effectiveness of the internal fixed media has not been as good as expected, and yields a rather low cost/benefit ratio.

It is proposed that external nitrification, i.e. external to the BNRAS system, will provide a more effective reduction in sludge age and aerobic mass fraction. If nitrification can be achieved independently of the BNRAS mixed liquor, the sludge age can be reduced from the usual 20 to 25 d to less than half, around 8 to 10 d. The reduction in sludge age increases the WW treatment capacity of the system by some 50% or, alternatively, reduces the biological reactor volume requirement per Mℓ WW treated by about a $^1/_3$, without negatively impacting either biological N or P removal: In fact, a reduction in sludge age increases both biological N and P removal per mass organic load (WRC, 1984; Wentzel et al., 1990) and this would be particularly beneficial for low temperature WWs (10 to 15°C). Because nitrification is no longer required, the aerobic mass fraction is governed by the P uptake process, for which aerobic mass fractions can be smaller than for nitrification.

Implementation of external nitrification

External nitrification can be achieved at wastewater treatment plants (WWTPs) where old trickling filter (TF) plants have been extended with a BNRAS system. There are many such WWTPs, particularly in South Africa. Often at these WWTPs, to retain the benefit of the old TF, a proportion of influent WW is passed through the TF and the effluent is (see Fig. 1):

- Discharged to the BNRAS system for biological N and P removal (e.g. Van Huyssteen et al., 1990). This in effect increases the TKN/COD and P/COD ratios of the WW discharged to the BNRAS system and increases the effluent N and P concentrations.
- Chemically treated to precipitate the P before discharge to the BNRAS system. This is not only costly, but also reduces the alkalinity of the water and only reduces the effective P/COD ratio of the WW on the BNRAS system.
- Irrigated on land at the WWTP. This practice will soon be carefully scrutinised in South Africa because it leads to a significant loss of valuable surface water.

If, instead of the above three strategies, the nitrification process is transferred to the TF, all the WW flow can be discharged to the BNRAS system (Fig. 2): A side-stream of mixed liquor is taken from the end of the anaerobic zone and passed through the TF 'humus' tanks (upgraded to internal secondary settling tanks) to remove the AS solids. The underflow sludge is discharged to the beginning of the anoxic zone and the overflow is passed onto the TF for nitrification. The nitrified TF effluent is then discharged to

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