The use of simultaneous chemical precipitation in modified activated sludge systems exhibiting biological excess phosphate removal Part 1: Literature review

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Abstract

Simultaneous chemical precipitation of phosphate (P) is commonly used in activated sludge systems to supplement biological excess P removal (BEPR). This paper briefly reviews the use of metal salts (typically iron or aluminium) for this purpose and focuses on the question of possible interference with the BEPR mechanism arising from the addition of chemical precipitant. Some evidence of weakened BEPR has emerged in activated sludge systems in South Africa, based partly on observations from full-scale plants in which controlled studies were not satisfactorily carried out. In some cases, extrapolations have been made either from laboratory-scale systems in which unrealistically large doses of metal precipitant were used, or from systems which were not operated close to steady-state conditions over extended periods. In other cases where simultaneous precipitation has been applied, the systems studied were not designed for BEPR. It was concluded that there is room for further investigation of the reported negative effect of simultaneous chemical precipitation on BEPR. To this end, a review of methods for fractionating the phosphorus compounds in activated sludge is presented. It does not appear to be possible to tailor a crude fractionation procedure to suit *specifically* the extraction of biologically-formed polyphosphate (polyP) separately from chemically-formed phosphorus precipitates in a complex medium such as activated sludge. More powerful analytical techniques are required to determine the nature, chain-length and mass of stored polyP in activated sludge. Similarly, there is a need to carry out further fundamental research into the interaction between the biological polymers in the sludge matrix and chemical removal mechanisms. Nevertheless, the available basic chemical fractionation procedures do make it possible to obtain a broad classification and measurement of chemical vs. biologically accumulated forms of P in activated sludge.

Introduction

Eutrophication of natural and man-made impoundments has become a problem in many countries, including South Africa. Problems associated with eutrophication include profuse algal blooms, excessive growth of nuisance aquatic plants, negative aesthetic aspects, deoxygenation, and problems relating to water purification for potable use. Many limnological studies have been conducted into the phenomenon, its causes and effects (*inter alia* Walmsley and Thornton, 1982; Walmsley and Thornton, 1984; Twinch, 1986; Grobler 1988 (a; b); Chutter, 1990; Dillon and Molot, 1996). Such studies have indicated that the limiting nutrients in eutrophication of freshwater systems are usually phosphorus and nitrogen (in that order), and that eutrophication can be controlled by significantly reducing the phosphorus (P) load discharged to a catchment. Worldwide increasing awareness of this causative effect on eutrophication has led to the introduction of legislation controlling the discharge of P to receiving waters.

In South Africa, the special phosphate standard was introduced, restricting the concentration of phosphorus in wastewater discharges to 1 mgP/ℓ as dissolved orthophosphate (*Government Gazette*, 1984). To comply with the new effluent legislation, a number of existing wastewater treatment plants in South Africa were modified or new plants constructed to implement biological excess phosphorus removal (BEPR) *[Also known as enhanced biological phosphorus removal (EBPR)]*. The decision to opt for biological P removal was based partly on the emergence of local expertise and partly on cost considerations. BEPR processes typically involve higher capital investment than those using chemical P precipitation; however, BEPR processes have the potential to offer lower operating and maintenance costs than conventional processes with chemical dosing. Similar trends have emerged in several countries, such as Canada, Australia and Germany (Nutt, 1985; Yue et al., 1987; Hartwig and Seyfried, 1991; Peter and Sarfert, 1991; Barnard, 1995; Hartley, 1997).

Since its implementation, considerable practical experience has been gained with BEPR systems. However, biological phosphorus (P) removal tends to be sensitive and subject to many fluctuations, making it difficult to achieve full compliance with discharge standards (*inter alia* Osborn et al., 1986; 1989; Lötter, 1991).

In many cases, the practical solution to meet effluent standards has been to supplement biological P removal with chemical P removal. Nutt (1985) investigated the technical and economic feasibility of retrofitting wastewater treatment plants with biological P removal. To consistently achieve less than 1.0 mg/ℓ as total P, Nutt (1985) found that BEPR processes require effluent filtration and/or supplementary chemical dosing. Similarly, the IAWQ Nutrient Removal Tour to South Africa (1993) highlighted that supplementary chemical dosing into biological nutrient removal (BNR) activated sludge plants was being used in several cases. In some cases, concern for over process optimisation has led to the use of "back-up" chemical dosing at the tertiary stage, followed by clarification, filtration or dissolved air flotation (DAF), in preference to simultaneous chemical addition at the secondary (activated sludge) stage (e.g. Hartwig and Seyfried, 1991; De Wet et al., 1992; Hamilton and Griffiths, 1997). Alternatively, side-stream processes

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Received 10 November 1998; accepted in revised form 20 June 2000.