Laboratory-scale investigation of biological phosphate removal from municipal wastewater

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Abstract

Biological phosphate removal in the wastewater treatment processes is an acknowledged phenomenon having gained worldwide support and can either be implemented independently or in synergy with chemical precipitation. The objective of this study was to evaluate the effect of biomass concentration on phosphate uptake. Procedures entailed exposing varying biomass concentrations to anaerobic environments for 2 h followed by aeration for 5 h to achieve phosphate uptake. Orthophosphate concentrations were determined after anaerobic and aerobic incubation using a Merck SQ118 spectrophotometer. There was a noticeable change in phosphate removal with changes in biomass concentration. Optimal phosphate removal was achieved at biomass concentration of 1 900 mg·ℓ^{-1}. The findings of this investigation suggest a direct relationship between biomass concentration and phosphate removal capacity.

Nomenclature

BPR	=	biological phosphorus removal
BNR	=	biological nutrient removal
COD	=	chemical oxygen demand
DO	=	dissolved oxygen
DWTP	=	Darvill wastewater treatment plant
EBPR	=	excess biological phosphorus removal
ML	=	mixed liquor
MLOSS	=	mixed liquor organic suspended solids
MLSS	=	mixed liquor suspended solids
P	=	phosphorus
Poly-P	=	poly-phosphate
SQ	=	spectroquant
UCT	=	University of Cape Town

Introduction

Due to rapid industrialisation there has been an increase in the amount of effluent being disposed to natural water bodies. Major contaminants found in wastewater include biodegradable, volatile and recalcitrant organic compounds, toxic metals, suspended solids, plant nutrients (nitrogen and phosphorus), microbial pathogens and parasites (Bitton, 1994). The discharge of nitrogen (as nitrate) and phosphorus (as phosphates) to inland rivers, lakes and dams causes massive growth of algae and plants due to the "fertiliser type" effect of the phosphate and nitrate (Steyn et al., 1975). This process is called **eutrophication** and disturbs the natural balance that exists in the water body. Phosphate is a more limiting factor than nitrate in eutrophication, because some bacteria and algae are able to fix atmospheric nitrogen and convert it to the more oxidisable states of nitrates and nitrites for growth (Wentzel, 1990). Therefore, reducing phosphorus concentrations to the lowest possible level is vital to the maintenance of unpolluted water supplies.

Biological phosphorus removal (BPR) is preferred by wastewater operators to chemical phosphorus removal since it lowers process costs and reduces the problem of mineralisation. Biological phosphorus removal techniques are based on the principle that, given optimal conditions, some heterotrophic bacteria in the activated sludge biomass are able to remove solubilised phosphates by accumulating them intracellularly in the form of polyphosphates.

During biological wastewater treatment it is the active biomass that is responsible for nutrient removal. Mixed liquor organic suspended solids (MLOSS) is composed of four components viz., heterotrophic active biomass; endogenous residue; inert material and autotrophic active biomass (Ubisi et al., 1997).

The original UCT model (Dold et al., 1980; Van Haandel et al., 1981) did not consider active heterotrophic or autotrophic biomass to be present in the municipal wastewater in South Africa. However, investigations in Europe have indicated that municipal wastewater can contain a significant heterotrophic active biomass fraction (Henze, 1989), up to 20% of the total COD (Kappeler and Gujer, 1992). It is the heterotrophic active biomass that is responsible for the uptake of phosphates in the form of polyphosphates. Some researchers maintain that the active fraction of bacteria in activated sludge flocs amounts to only 1 to 3% of the total bacterial population whereas the other 97 to 99% can be referred to as inactive (Hanel, 1988).

The concentration of suspended solids in the aeration tank, commonly referred to as mixed liquor suspended solids (MLSS), is a crude measure of the biomass within the aeration tank. Normal MLSS concentrations range from 1 500 to 3 500 mg·ℓ^{-1} for conventional activated sludge units, rising to 8 000 mg·ℓ^{-1} for high-rate systems (Gray, 1989). In theory, the higher the MLSS concentration in the aeration tank the greater the efficiency of the process as there is a greater biomass concentration to utilise available COD or nutrients (Gray, 1989). Decreasing excess biological phosphorus removal (EBPR) efficiencies were always synonymous with decreasing poly-P bacterial counts (Cech et al., 1991, Cech and Hartman, 1993). Biomass in an enhanced phosphate removal process is capable of accumulating phosphorus in excess of 3%; in some cases sludge phosphorus contents of up to 18% have been obtained with artificial, tailored substrates (Appeldoorn et al., 1992).

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