Filamentous organism bulking in nutrient removal activated sludge systems

Paper 11: A biochemical/microbiological model for proliferation of anoxic-aerobic (AA) filamentous organisms

TG Casey, MC Wentzel and GA Ekama*

University of Cape Town, Department of Civil Engineering, Rondebosch 7701, Cape, South Africa

Abstract

A model is presented that describes the competitive growth behaviour of floc-forming and anoxic-aerobic (AA) filamentous organisms in long sludge age nitrogen (N) and nitrogen and phosphorus (N&P) removal activated sludge systems. The model, referred to as the bulking model, establishes the potential for filamentous organism proliferation under various aeration and substrate feeding regimes. Based on the principles of the model, system configuration and operational procedures are proposed for the amelioration of bulking and are tested experimentally. To examine the general applicability of the bulking model it is tested by applying it to the experiments described by Lakay et al. (1999) and Musvoto et al. (1999). [*Note: Throughout description of the bulking model, the terms filamentous and filaments refer specifically to AA filaments (formerly designated low F/M filaments), which are associated with poorly settling sludges in long sludge age N and N&P removal systems*].

List of symbols

AA	=	anoxic-aerobic filaments
ADP	=	adenosine diphosphate
AOOs	=	ammonia oxidising organisms
ATP	=	adenosine triphosphate
COD	=	chemical oxygen demand
Cyt	=	cytochrome
DSVI	=	dilute sludge volume index (mℓ/g)
DO	=	dissolved oxygen (mgO/ℓ)
ETP	=	electron transport pathway
FAD	=	flavin adenine dinucleotide
FeS	=	iron-sulphur complexes
FMN	=	flavomononucleotide
NAD	=	nicotinamide adenine dinucleotide
NaR	=	nitrate reductase
ND	=	nitrification-denitrification system
NDBEPR	=	nitrification-denitrification biological excess phosphorus removal
NiR	=	nitrite reductase
NOOs	=	nitrite oxidising organisms
NOR	=	nitric oxide reductase
N_2OR	=	nitrous oxide reductase
Q	=	ubiquinone
RBCOD	=	readily biodegradable COD
SBCOD	=	slowly biodegradable COD
TKN	=	total Kjeldahl nitrogen (mgN/ℓ)
VSS	=	volatile suspended solids (mg/ℓ)
2RND	=	2 reactor nitrification denitrification system

* To whom all correspondence should be addressed.
☎(021) 650-2588; fax (021) 689-7471; e-mail ekama@engfac.uct.ac.za
Received 11 November 1998; accepted in revised form 27 May 1999.

Introduction

The objective of the conceptual biochemical model for aerobic facultative heterotrophic organism respiration developed by Casey et al. (1999a, b) was to establish a basis by which the mechanisms of respiration of the facultative organism mass in activated sludge could be understood. In this paper, the biochemical model is applied to filamentous and floc-forming organisms, to develop a microbiological model for substrate competition by these organisms as a means of explaining the proliferation of AA (low F/M) filaments in N and N&P removal systems. Implicit to the formulation of the AA filament bulking model is the assumption of the biochemical model, that both filamentous and floc-forming organisms are aerobic facultative heterotrophic organisms. Filamentous organisms that are considered to be AA filaments are those that proliferate in N and N&P removal systems and sort into Jenkins et al. (1984) low F/M group, viz. *Microthrix parvicella*, and types 0092, 0041, 0675, 1851, 0914 and 0803.

Statement of hypothesis

In activated sludge systems, floc-formers and filaments compete for mutually growth-limiting substrate. Under completely aerobic or completely anoxic conditions, the floc-formers outcompete the filaments for substrate due to higher substrate utilisation rates, and filament growth is restricted. In ND and NDBEPR activated sludge systems, competition between filamentous and floc-forming organisms for mutually growth-limiting substrate is influenced by inhibition of substrate utilisation by floc-formers under aerobic conditions. Under anoxic conditions, in utilisation of substrate the floc-formers execute the denitrification of nitrate through each of the denitrification intermediates to dinitrogen as follows:

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

nitrate → nitrite → nitric oxide → nitrous oxide → dinitrogen