

Filamentous organism bulking in nutrient removal activated sludge systems

Paper 9: Review of biochemistry of heterotrophic respiratory metabolism

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Abstract

Biochemical mechanisms for respiration by facultative organisms are reviewed in two sequential parts. In Part I, the biochemical reactions involved in the utilisation of substrate under aerobic and under anoxic conditions are outlined. In Part II, the mechanisms which initiate, regulate, and terminate respiration under each of aerobic and anoxic conditions are described. A consequence of Part II is identification of a series of conditions and mechanisms in which one of the intermediates of denitrification (nitrite, or nitric oxide) interacts with the aerobic respiratory enzymes (the cytochrome oxidases), resulting in inhibited aerobic respiration when organisms are alternately exposed to anoxic and aerobic conditions. This mechanism is an important aspect of a conceptual biochemical model for facultative heterotrophic organisms developed in Paper 10 (Casey et al., 1999a).

List of symbols

AA	=	anoxic-aerobic
CoA	=	coenzyme A
ADP	=	adenosine diphosphate
aq	=	aqueous
ATP	=	adenosine triphosphate
ATPase	=	adenosine triphosphatase
cs	=	cysteine
cyt	=	cytochrome
DO	=	dissolved oxygen
ETP	=	electron transport pathway
FAD	=	flavin adenine dinucleotide - oxidised
FADH ₂	=	flavin adenine dinucleotide - reduced
FMN	=	flavin mononucleotide - oxidised
FMNH ₂	=	flavin mononucleotide - reduced
Fp	=	flavoprotein
g	=	gaseous
GTP	=	guanosine triphosphate
hs	=	histidine
NAD ⁺	=	nicotinamide adenine dinucleotide - oxidised
NADH	=	nicotinamide adenine dinucleotide - reduced
NaR	=	nitrate reductase
NiR	=	nitrite reductase
NOR	=	nitric oxide reductase
N ₂ OR	=	nitrous oxide reductase
NO	=	nitric oxide
NO ₂ ⁻	=	nitrite
NO ₃ ⁻	=	nitrate
N ₂	=	dinitrogen
N ₂ O	=	nitrous oxide
O ₂ UR	=	oxygen utilisation rate
Q	=	ubiquinone
QH ₂	=	ubiquinol (reduced ubiquinone)
TCA	=	tricarboxylic acid (cycle)

Introduction

The intention of this review is to outline the pertinent information and research which contributes to an understanding of and provides a basis for development of the conceptual respiratory model for facultative heterotrophic organisms described in Paper 10 (Casey et al., 1999a) of this series and the conceptual microbiological model for bulking by AA filaments (Casey et al., 1999b, Paper 11).

A considerable portion of the information set out in this paper is well accepted and widely documented in the microbiology and biochemistry literature and consequently, where general microbiology and biochemistry is described, it is not referenced. However, where information important to the bulking hypothesis is described or where research in an area is still being extensively conducted, references are cited to support the statements.

In the previous paper (Musvoto et al., 1999, Paper 8) of this series it was concluded that a more fundamental understanding is required of the biochemical mechanisms involved in respiration by aerobic facultative organisms. This is a consequence of the finding that AA filamentous organisms proliferate in activated sludge when this is cycled between anoxic and aerobic conditions. This cycling requires the organisms to utilise different electron transport pathways under each condition.

To examine this, a literature review is conducted, the objective of which is to identify the principal ETPs employed by facultative heterotrophic organisms under aerobic, anoxic, and alternating anoxic-aerobic conditions. This review is limited to facultative heterotrophic organisms since these are the organisms likely to be present under the cyclic anoxic-aerobic conditions found in activated sludge plants.

Background

Metabolism can be broadly described as the manner by which facultative heterotrophic organisms derive energy and matter for growth. It consists of two processes: the enzymatic biosynthesis of the complex molecular components of the organism itself (anabolism); and the enzymatic bio-reactions which generate energy to perform this biosynthesis (catabolism). The process of catabolism,

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