Activated sludge mixed liquor heterotrophic active biomass

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Abstract

In the current steady state design and kinetic simulation models for activated sludge systems, the heterotrophic active biomass is a key parameter. However, this parameter remains hypothetical within the structure of the models; it has not been measured directly, primarily due to the lack of suitable simple experimental techniques. In this paper a simple batch test procedure is used to quantify the heterotrophic active biomass concentrations of mixed liquor samples drawn from a well-defined anoxic/aerobic activated sludge system. The measured heterotrophic active biomass concentrations are in close agreement with those calculated theoretically using the steady state design and kinetic simulation models. This agreement provides substantive direct evidence supporting both the models and the experimental method.

List of abbreviations

ATP	=	adenosine triphosphate
BEPR	=	biological excess phosphorus removal
COD	=	chemical oxygen demand
DNA	=	deoxyribonucleic acid
DO	=	dissolved oxygen
(ML)	=	mixed liquor
(ML+WW)	=	mixed liquor and waste water
N	=	nitrogen
OUR	=	oxygen utilisation rate
TKN	=	total Kjeldahl nitrogen
TSS	=	total suspended solids
VSS	=	volatile suspended solids
(WW)	=	waste water

Introduction

To optimise the design and operation of the single sludge activated sludge system, over the past two decades a number of steady state design models (e.g. Marais and Ekama, 1976; WRC, 1984; Wentzel et al., 1990; Scheer and Seyfried, 1993; Maurer and Gujer, 1994) and kinetic simulation models (e.g. Dold et al., 1980; 1991; Van Haandel et al., 1981; Henze et al., 1987; Wentzel et al., 1992; Gujer et al., 1995; Henze et al., 1995) have been developed, to progressively include aerobic COD removal and nitrification, anoxic denitrification and anaerobic/anoxic/aerobic BEPR.

In terms of these design procedures and kinetic models, in the bioreactor of the non-nitrifying aerobic activated sludge system the mixed liquor organic suspended solids is made up of three components: heterotrophic active biomass; endogenous residue; and inert material. In the nitrifying aerobic and anoxic/aerobic activated sludge systems, a fourth mixed liquor organic suspended solids component is included: autotrophic active biomass. The heterotrophic active biomass arises from synthesis of living heterotrophic organisms on biodegradable organic substrates and is "lost" via endogenous respiration/death processes; in the activated sludge system this mixed liquor component performs the biodegradation processes of COD removal and denitrification. The autotrophic active biomass arises from synthesis of autotrophic organisms in the nitrification of ammonia to nitrate under aerobic conditions and is "lost" via endogenous respiration/death processes. The endogenous residue is generated from the unbiodegradable portion of the heterotrophic and autotrophic active biomasses that are lost in the endogenous respiration/death processes. The inert material arises from the influent wastewater unbiodegradable paniculate organics which, on entry into the bioreactor, are enmeshed in the mixed liquor organic suspended solids. All four mixed liquor organic suspended solids components settle out in the secondary settling tank and are returned to the bioreactor via the underflow recycle; these components leave the activated sludge system via the waste flow.

If an anaerobic reactor is included in the system to stimulate BEPR, additionally the organisms mediating the BEPR [variously termed polyP organisms (Wentzel et al., 1986), bioP organisms (Comeau et al., 1986), phosphate accumulating organisms, PAO (Henze et al., 1995)] will contribute to the mixed liquor organic suspended solids - to avoid this complication, only the aerobic and anoxic/aerobic systems will be considered in this paper.

Historically the mixed liquor organic suspended solids has been measured as a lumped parameter, via the VSS test *{Standard Methods,* 1985), or, more recently, the COD test. However, from the description above, in the bioreactor of the aerobic and anoxic/aerobic activated sludge systems only a part of the mixed liquor organic suspended solids is heterotrophic active biomass, the active fraction, and only this part mediates the biological processes of COD removal and denitrification. Currently, the heterotrophic active biomass exists only as a hypothetical parameter within the structure of the design procedures and kinetic models. Although indirect evidence provides support for this parameter (by consistency between observations and predictions over a wide range of conditions, e.g. Dold et al., 1980, 1991; Van Haandel et al., 1981; Warner et al., 1986), it has not been directly measured experimentally and compared to the theoretical values. The problem in measurement of this parameter has been the lack of suitable experimental techniques. In the literature, principally microbiological techniques have been proposed; for example, pour plate or other culturing techniques (e.g. Gaudy and Gaudy, 1980), ATP analysis (Nelson and Lawrence, 1980), DNA analysis (Liebeskind and Dohmann, 1994), using fluorescent probes for ribosomal RNA (Wagner et al., 1994), sequencing of ribosomal

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Received 29 July 1996; accepted in revised form 6 December 1996.