EVALUATION OF BIOMASS AGE IN ACTIVATED SLUDGE PROCESSES

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Abstract. A criterion is proposed for evaluating biomass age in the activated sludge treatment process in which the biological reaction may be likened to completely mixed reactors operated in series. Expressions for a single-unit reactor have been deduced from the general expression, and these are shown to be equivalent to those reported in the art, and for plug flow reactor.

1. Introduction

Micro-organism activity in a biochemical process not only depends on environmental factors (pH, temperature, substrate features, etc.) but on micro-organism physiological and morphological states as well.

'Biomass age' has recently been introduced as a feature to describe the biomass state in the activated sludge process (Giona et al., 1979). It not only typifies activated sludge processes better than the 'sludge age' previously used (Jenkins and Garrison, 1968; Lawrence and Mc Carty, 1970; Burchett and Tcobanoglu, 1974), but it may also be used as a parameter to express the functional relationship between microbial population metabolism values and biomass 'state'.

An earlier paper (Giona et al., 1979) defined the expressions used for biomass age determination in a completely mixed reactor (CMR). From an analysis of experimental data, the kinetics of the activated sludge process was derived in terms of biomass age and temperature conditions.

The aim of this paper is to propose a general formulation for expressing biomass age that may be used regardless of aeration tank set up.

2. Biomass Age in a CMR with Recycle

The biomass age \( t_s \) in an activated sludge CMR with recycle may be defined by:

\[
t_s = 1/\mu_n,
\]

where \( \mu_n \) is the biomass specific net growth rate inclusive of endogenous phenomena.

Equation (1), which is clearly only valid when \( \mu_n \geq 0 \) has been used by a number of authors to calculate sludge age (Sherrard and Schroeder, 1972; Goodman and Englande, 1974). It may be noted that the expression for \( \mu_n \) gives the same values for concentrations expressed in terms of VSS (volatile suspended solids) as well as for those that only refer
to the active part of sludge. Consequently, Equation (1) leads to biomass and sludge ages being expressed with the same numerical values.

Now, Equation (1) may be expressed in different, though mutually equivalent forms. In fact, if we consider the in-reactor biomass balance equation (Figure 1):

$$A_0 x_0 + \mu_n x_1 V = A_1 x_1,$$

where $A$ indicates the flow rate, $x$ the biomass concentration and $V$ the reactor volume,

the subscripts 0 and 1 are pertaining respectively to the influent and effluent streams, we obtain

$$\mu_n = \frac{A_1 x_1 - A_0 x_0}{x_1 V}$$

and, because

$$A_1 x_1 - A_0 x_0 = A_e x_e + A_u x_u$$

if flow $A$ contains no biomass, we obtain

$$t_s = \frac{x_1 V}{A_e x_e + A_u x_u}$$

where the subscripts $e$ and $u$ refer to the clarified effluent stream and to the waste sludge stream respectively.

Equation (3) thereby shows that biomass age can be calculated as the ratio between in-reactor and out-flowing biomass (Jenkins and Garrison, 1968; Goodman and Englande, 1974).

From Equation (2), and because $A_0 = A_1$, we have

$$\varphi = x_0 / x_1 = 1 - \mu_n \tau$$

where $\tau$ is the volumetric residence time inside the reactor, defined by:

$$\tau = V / A_0.$$