MODELING THE DECAY OF HETEROPTROPHIC BIOMASS: ENDOGENEOUS RESPIRATION versus DEATH REGENERATION

In a biological system microorganisms are known to die and decay. This results in a reduction in active volatile organism mass with time. Two approaches have developed to describe the process of organism decay in a biological wastewater treatment system:

1. Endogenous Respiration Approach;

Endogenous Respiration

Endogeneous respiration has been attributed to an energy requirement for organism maintenance, where a fraction of the active organism mass is oxidized to provide energy for the maintenance of the mass remaining. The mass of organisms that “disappears” is directly equated to the oxygen consumption for endogenous respiration. An unbiodegradable fraction remains, and accumulates as endogenous residue.

The endogenous decay rate is modeled as a first order process with respect to the active heterotroph biomass concentration:

$$\frac{dZ_{BH}}{dt} = -b \cdot Z_{BH}$$  \hspace{1cm} (1)

$$Z_{BH} = \text{Active heterotroph biomass concentration (mgCOD/L)}$$

$$b = \text{Specific endogenous decay rate (d\textsuperscript{-1})}$$

A fraction (f) of the mass that disappears remains as endogenous residue; the rate of accumulation is given by:

$$\frac{dZ_{E}}{dt} = f \cdot b \cdot Z_{BH}$$  \hspace{1cm} (2)

$$Z_{E} = \text{Endogenous residue concentration (mgCOD/L)}$$

$$f = \text{Endogenous residue fraction}$$

The nett organism mass that disappears (mgCOD/L/d) is equated to the oxygen consumption for endogenous respiration:

$$O_{E} = (1 - f) \cdot b \cdot Z_{BH}$$  \hspace{1cm} (3)

$$O_{E} = \text{Oxygen consumed for endogenous respiration (mgO/L/d)}$$

The endogenous decay rate parameter, b, is determined experimentally by aerating a batch of mixed liquor for a period of several days, while monitoring the oxygen uptake rate (OUR). The value of b (0.24 d\textsuperscript{-1} at 20\textdegree C) is given by the slope of a semi-logarithmic plot of OUR versus time [with an endogenous residue fraction, f, of 0.20].
A necessary requirement for applying the endogenous respiration approach for modeling organism decay is that an electron acceptor must be available – either oxygen or nitrate in activated sludge systems. This approach does not cover the situation for modeling organism decay in systems incorporating anaerobic zones or phases. The death-regeneration approach was introduced by Dold, Ekama and Marais (1980) as a simple alternative modeling approach to account for organism decay in systems with aerobic, anoxic and anaerobic zones.

**Death-Regeneration**

In the death-regeneration approach it is assumed that active heterotrophic organisms die at a certain rate. A fraction of the organism mass accumulates as endogenous residue, and the remaining fraction is lyzed as biodegradable substrate. The lyzed substrate adds to the biodegradable substrate from the influent. The “endogeneous oxygen demand” is exerted when the lyzed substrate is utilized for synthesis of new organism mass (i.e. regeneration).

The organism death is modeled as a first order process with respect to the active heterotroph biomass concentration:

\[
\left( \frac{dZ_{BH}}{dt} \right)_D = -b' \cdot Z_{BH}
\]  

\(b' = \) Specific organism death rate \((d^{-1})\)

A fraction \((f')\) of the mass that dies remains as endogenous residue; the rate of accumulation is given by:

\[
\frac{dZ_E}{dt} = f' \cdot b' \cdot Z_{BH}
\]  

\(f' = \) Endogenous residue fraction

The rate that biodegradable substrate is released from organism death is:

\[
\left( \frac{dS}{dt} \right)_D = (1 - f') \cdot b' \cdot Z_{BH}
\]  

The rate of synthesis (i.e. regeneration) of organism mass from this biodegradable substrate is:

\[
\left( \frac{dZ_{BH}}{dt} \right)_R = Y_H \cdot (1 - f') \cdot b' \cdot Z_{BH}
\]  

\(Y_H = \) Heterotroph yield coefficient \((\text{mg organism COD/mg COD})\)

The oxygen consumption associated with regeneration is:

\[
O'_E = (1 - Y_H) \cdot (1 - f') \cdot b' \cdot Z_{BH}
\]  

The nett loss of active organism mass is the difference between Eqs. (4) and (7):

\[
\left( \frac{dZ_{BH}}{dt} \right) = -b' \cdot Z_{BH} + Y_H \cdot (1 - f') \cdot b' \cdot Z_{BH} = [-b' + Y_H \cdot (1 - f') \cdot b'] \cdot Z_{BH}
\]
Equivalence of Endogenous Respiration and Death-Regeneration Approaches

The two approaches for modeling organism decay should yield the same results under steady state conditions. That is, the nett disappearance of active organism mass, the generation of endogenous residue, and the oxygen consumption associated with organism decay should be equal. Equating Eqs. (2) and (5) and Eqs. (1) and (9):

\[ f \cdot b = f' \cdot b' \quad (10) \]

\[ -b = -b' + Y_H \cdot (1 - f') \cdot b' \quad (11) \]

Solving for \( b' \) and \( f' \):

\[ b' = \left[ \frac{1 - Y_H \cdot f}{1 - Y_H} \right] \cdot b \quad (12) \]

\[ f' = \left[ \frac{1 - Y_H}{1 - Y_H \cdot f} \right] \cdot f \quad (13) \]

Substituting values from the endogenous respiration approach yields the equivalent parameter values for the death-regeneration approach:

\[ b' = \left[ \frac{1 - Y_H \cdot f}{1 - Y_H} \right] \cdot b = \left[ \frac{1 - 0.666 \cdot 0.20}{1 - 0.666} \right] \cdot 0.24 = 0.63 \text{ d}^{-1} \]

\[ f' = \left[ \frac{1 - Y_H}{1 - Y_H \cdot f} \right] \cdot f = \left[ \frac{1 - 0.666}{1 - 0.666 \cdot 0.20} \right] \cdot 0.20 = 0.08 \]

The oxygen consumption for the two approaches should be equal. Substituting in Eqs. (3) and (8):

\[ O_E = (1 - f) \cdot b \cdot Z_{BH} = (1 - 0.20) \cdot 0.24 \cdot Z_{BH} = 0.19 \cdot Z_{BH} \]

\[ O'_E = (1 - Y_H) \cdot (1 - f') \cdot b' \cdot Z_{BH} = (1 - 0.666) \cdot (1 - 0.08) \cdot 0.62 \cdot Z_{BH} = 0.19 \cdot Z_{BH} \]

Reference