Summer School 2012

Tecnologie sostenibili per la tutela dell'ambiente

Politecnico di Milano 25 Giugno 2012

MATHEMATICAL MODELLING OF MULTISPECIES BIOFILM FOR WASTEWATER TREATMENT

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Acc.V 15.0 kV	Spot 3.0	Magn 2500x	Det SE	WD 9.4	Exp 1	Spike	10 µm		

A biofilm is "a layer of prokaryotic and eukaryotic cells anchored to a substratum surface and embedded in an organic matrix of biological origin"



APPLICATIONS

Bacteria in biofilms are protected from washout

Physical structure allowing for distinct biological niches

Microbial activity can modify the internal environment

Variety of microbial groups contributing to the conversion of different organic and inorganic substrates

Resistance to antimicrobial agents

Removing contaminants from soil or ground water

- Crucial for cycling nutrients in the Earth's biosphere
- Wastewater treatment (since 19th)

Biofilm definition



WHY MODELLING?

(1) MODELS ARE THE BASIC TOOLS FOR ENGINEERING

(2) MODELS HELPS US ACHIEVE A BETTER UNDERSTANDING OF THE PROCESS



<u>GOALS FOR</u> <u>BIOFILM</u> <u>MODELLING</u>



UNDERSTAND FUNDAMENTAL MECHANISMS LINK DIFFERENT TYPES OF MECHANISMS

PRE-MODEL EXPERIMENTAL DESIGN

CREATE NOVEL PROCESS DESIGNS

IMPROVE THE PERFORMANCE OF A PROCESS

Biofilm Modelling



Objectives research plan

FIRST GENERATION MODELS (1970s)

- •Harris and Hansford 1976
- Harremoes 1976
- ·LaMotta 1976
- •Williamson and McCarty 1976
- Rittmann and McCarty

SECOND GENERATION MODELS (1980s)

- •Kissel et al. 1984
- •Wanner and Gujer 1984,1986
- •Rittmann and Manem 1992

THIRD GENERATION MODELS (since 1990s)

- Picioreanu et al. 1998,2001,2004
- •Noguera et al. 1999
- •Kreft et al. 1998,2001
- •Eberl et al. 2001
- Pizarro et al. 2001
- •Xavier et al. 2005



CONTINUUM MODELS	 do not take directly into account small-scale details of an individual microrganism; generate deterministic solutions ; biofilm density, porosity and surface shape are to be specified as model input; difficult to derive and handle numerically
DISCRETE– DIFFERENTIAL MODELS	 represent typical structural heterogeneity of biofilm; elements of randomness; use of abstract mathematical parameters



INVESTIGATOR

Wanner and Gujer 1986







A Multidimensional Multispecies Continuum Model for Heterogeneous Biofilm Development (Klapper et al., 2007) EQUATIONS: CONSERVATION OF MASS

Transport by diffusion is several orders of magnitude faster than changes due to growth and advection . So it will be considered quasi steady state for substrate balance.

Transport of biomass is governed by an advective process

 Continuum models' simulations are based upon accepted numerical methods with an existing error analysis
 Concentrations of biomass may be described by one or more density fields, that obey to some sort of conservation law (mass or momentum)
 Generation of determinsitic solutions...possibility of analytical study
 Applied to a planar biofilm system, the model reduces to a onedimensional model equivalent to W.-G.





$$\frac{\partial}{\partial t}X_i(z,t) + u(z,t)\frac{\partial}{\partial z}X_i(z,t) = \rho_i r_{M,i}(z,t,\mathbf{X},\mathbf{S}) - X_i(z,t)\frac{\partial}{\partial z}u(z,t), \ 0 < z \le L(t), \ t > 0,$$

$$\begin{aligned} \frac{\partial}{\partial z}u(z,t) &= \sum_{i=1}^{n} r_{M,i}(z,t,\mathbf{X},\mathbf{S}), \ 0 < z < L(t), \ t > 0, \ i = 1, \dots n, \\ \dot{L}(t) &= u(L(t),t) + \sigma, \ t > 0, \\ \frac{\partial}{\partial t}S_{j}(z,t) - \frac{\partial}{\partial z}\left(D_{j}\frac{\partial}{\partial z}S_{j}(z,t)\right) &= r_{S,j}(z,t,\mathbf{X},\mathbf{S}), \ 0 < z < L(t), \ t > 0, \ j = 1, \dots m. \end{aligned}$$

a) Improving developed model in terms of time calculation
b) Develop a 2D model
c) Set-up a lab-scale reactor

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Future actvities

THANKS FOR THE ATTENTION