Desviaciones de la idealidad fluidodinámica

- Partimos de los conceptos de los reactores ideales:
  - Mezcla completa: todos los puntos del volumen de control tienen el mismo valor en las variables de estado. Consecuencia: su dinámica se puede representar por una EDO en el tiempo; para el diseño se reduce a una ecuación algebraica.
  - Flujo pistón: no hay mezcla en la dirección de flujo, hay una variación continua de las variables de estado a lo largo de la dirección de flujo. Consecuencia: se requieren EDP (tiempo y espacio) para representar la dinámica y EDO (en el espacio) para el diseño. En la práctica se discretiza el espacio y se resuelve cada elemento como si tuviera mezcla completa, la salida de uno es la entrada del siguiente, etc.
- Estos son modelos que pueden caracterizarse con un solo parámetro:

El Tiempo de Residencia Hidráulico

- Sobre la base del concepto de Rector Flujo Pistón se desarrolla el concepto de Reactor con Dispersión. La ecuación que caracteriza este reactor tiene un término que involucra la derivada segunda respecto a la distancia. Dependiendo de las condiciones de contorno da lugar a distintas soluciones, pero en definitiva, además de tener como parámetro el TRH depende de otro parámetro asociado a la dispersión

- Sobre la base del concepto de tanque agitado se desarrolla el modelo de Tanques en Serie, donde además del TRH (igual para todos los tanques) se añade como parámetro el número de tanques.

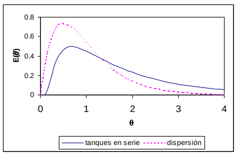
Distribuciones de Tiempos de Residencia más usadas

Tanques en serie

$$E(\theta)=\frac{N^{N}}{(N-1)!}\theta^{(N-1)}e^{-N\theta}$$

Dispersión

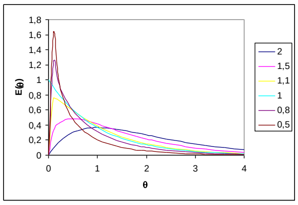
$$E(\theta)=\frac{1}{2}\sqrt{\frac{Pe}{\pi\theta}}\exp\left\{-\frac{Pe(1-\theta)^{2}}{4\theta}\right\}$$

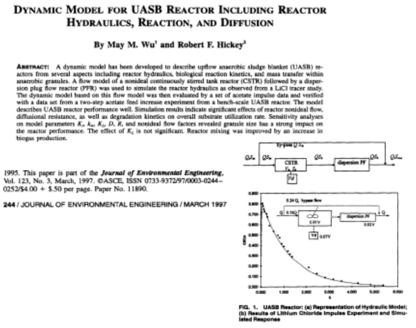


Tanques en serie “extendida” (distribución Gamma)

$$E(\theta)=\frac{N^{N}}{\Gamma(N)}\theta^{(N-1)}e^{-N\theta}$$

$$\Gamma(x)=\int_{0}^{\infty}e^{-u}u^{(x-1)}du$$





DYNAMIC MODEL FOR UASB REACTOR INCLUDING REACTOR HYDRAULICS, REACTION, AND DIFFUSION

By May M. Wu[1] and Robert F. Hickey[2]

ABSTRACT: A dynamic model has been developed to describe upflow anaerobic sludge blanket (UASB) reactors from several aspects including reactor hydraulics, biological reaction kinetics, and mass transfer within anaerobic granules. A flow model of a nonideal continuously stirred tank reactor (CSTR) followed by a dispersion plug flow reactor (PFR) was used to simulate the reactor hydraulics as observed from a LiCl tracer study. The dynamic model based on this flow model was then evaluated by a set of acetate impulse data and verified with a data set from a two-step acetate feed increase experiment from a bench-scale UASB reactor. The model describes UASB reactor performance well. Simulation results indicate significant effects of reactor nonideal flow, diffusional resistance, as well as degradation kinetics on overall substrate utilization rate. Sensitivity analyses on model parameters K_s, k_m, K_L, D, R, and nonideal flow factors revealed granule size has a strong impact on the reactor performance. The effect of K_L is not significant. Reactor mixing was improved by an increase in biogas production.

1995. This paper is part of the *Journal of Environmental Engineering*, Vol. 123, No. 3, March, 1997. ©ASCE, ISSN 0733-9372/97/0003-0244–0252/$4.00 + $.50 per page. Paper No. 11890.

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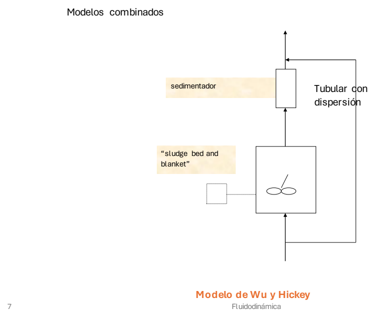
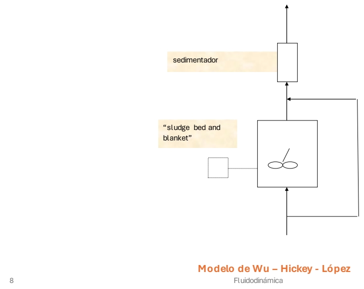
FIG. 1. UASB Reactor: (a) Representation of Hydraulic Model; (b) Results of Lithium Chloride Impulse Experiment and Simulated Response

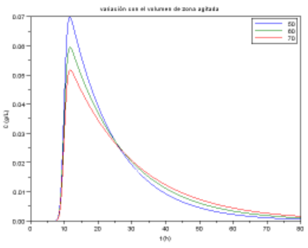


Modelos combinados

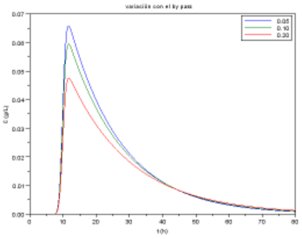
Modelo de Wu y Hickey



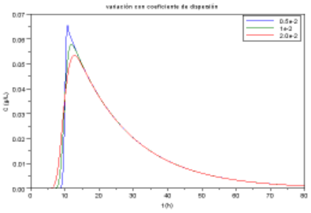
Modelo de Wu – Hickey - López



variación con el volumen de zona agitada



variación con el by pass



variación con coeficiente de dispersión

Modeling the Liquid Flow in Up-Flow Anaerobic Sludge Blanket Reactors

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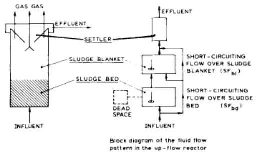
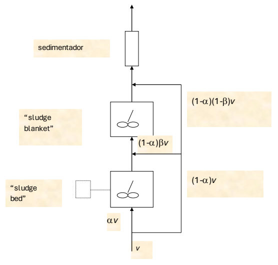
Biotechnology and Bioengineering, Vol. XXVIII, Pp. 1615–1620 (1986)



Block diagram of the fluid flow pattern in the up-flow reactor

Figure 1. The up-flow reactor schematically.



Modelo de Bolle *et al.*

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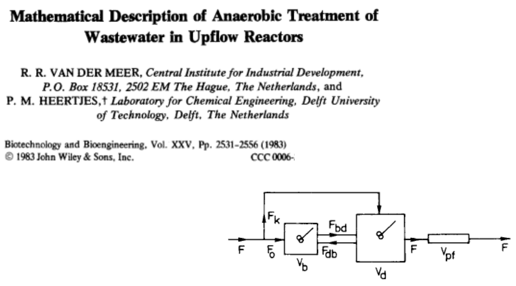

Mathematical Description of Anaerobic Treatment of Wastewater in Upflow Reactors

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Biotechnology and Bioengineering, Vol. XXV, Pp. 2531–2556 (1983)
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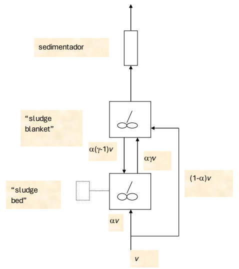

Modelo de Van der Meer

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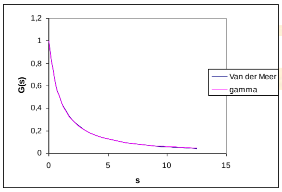
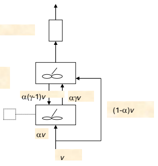
Van der Meer

$$G(s)=\frac{[(1-\alpha)a\tau]s+\alpha\gamma}{[a(1-a)\tau^2]s^2+[\alpha\gamma-a-\alpha a]\tau\ s+\alpha^2\gamma(\gamma-1)}$$

Gamma

$$G(s)=\left(\frac{1}{1+\frac{\tau}{N}s}\right)^N$$





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Condiciones de las experiencias de Van der Meer y parámetros de las distribuciones de Van der Meer y gamma.

Experiencia	α	γ	a	X (kgSS)	u_L (m/h)	u_G (m/h)	N	r^2
Lab. 1	0.40	2.63	0.19	-	0.36	0.27	1.104	0.99999..
Lab. 2	0.20	2.25	0.07	-	0.36	0.16	1.053	0.99999..
Lab. 3	0.80	2.14	0.35	-	0.41	0.39	1.319	0.99995..
Lab. 4	0.80	3.00	0.35	-	0.68	0.31	1.244	0.99990..
Lab. 6	0.95	3.71	0.30	-	0.27	0.12	1.237	0.99977..
Completa 1	0.39	5.10	0.18	1795	0.80	0.27	1.065	0.99998..
Completa 2	0.29	6.52	0.22	3510	0.47	0.43	1.025	0.99999..
Completa 3	0.14	12.43	0.11	6465	0.55	1.04	1.0066	0.99999..
Completa 4	0.17	10.41	0.12	5565	0.69	0.92	1.0118	0.99999..

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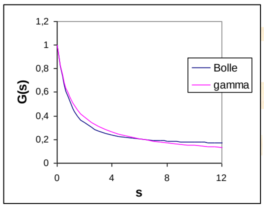
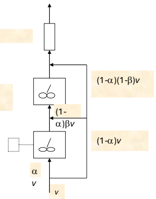
Bolle *et al.*

$$G(s)=(1-\alpha)(1-\beta)+(\alpha+\beta-\alpha\beta)G_2(s)$$

$$G_2(s)=\frac{\beta(1-\alpha)\left[s+\frac{\alpha}{a\tau}\right]+\frac{\alpha^2}{a\tau}}{[(1-a)\tau\ s+\alpha+\beta-\alpha\beta]\left[s+\frac{\alpha}{a\tau}\right]}$$





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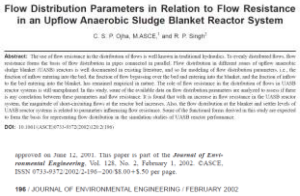

Flow Distribution Parameters in Relation to Flow Resistance in an Upflow Anaerobic Sludge Blanket Reactor System

C. S. P. Ojha, M.ASCE,[1] and R. P. Singh[2]

Abstract: The use of flow resistance in the distribution of flows is well known in traditional hydraulics. To evenly distributed flows, flow resistance forms the basis of flow distribution in pipes connected in parallel. Flow distribution in different zones of upflow anaerobic sludge blanket (UASB) reactors is well documented in existing literature, and so far modeling of flow distribution parameters, i.e., the fraction of inflow entering into the bed, the fraction of flow bypassing over the bed and entering into the blanket, and the fraction of inflow to the bed entering into the blanket, has remained empirical in nature. The role of flow resistance in the distribution of flows in UASB reactor systems is still unexplained. In this study, some of the available data on flow distribution parameters are analyzed to assess if there is any correlation between these parameters and flow resistance. It is found that with an increase in flow resistance in the UASB reactor system, the magnitude of short-circuiting flows at the reactor bed increases. Also, the flow distribution at the blanket and settler levels of UASB reactor systems is related to parameters influencing flow resistance. Some of the functional forms derived in this study are expected to form the basis for representing flow distribution in the simulation studies of UASB reactor performance.

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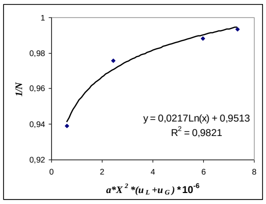
Parámetro de la Distribución Gamma en función del parámetro de resistencia de Ojha y Singh



Para un macrofluido

$$\frac{\overline{C_A}}{C_{Ain}} = \int_0^\infty \left(\frac{C_A(t)}{C_{Ain}}\right) E(t)dt$$

Si es una cinética de primer orden

$$\frac{\overline{C_A}}{C_{Ain}} = \int_0^\infty e^{-kt} E(t)dt$$

$$\frac{\overline{C_A}}{C_{Ain}} = G(k)$$

Supongamos el proceso de degradación como dos reacciones de primer orden en serie

$$S_1 \xrightarrow{k_1} S_2 \xrightarrow{k_2} M$$

$$\frac{S_1}{S_{1in}} = e^{-k_1 t}$$

$$\frac{S_2}{S_{2in}} = \left[1 - \frac{k_1}{k_2 - k_1}\frac{S_{1in}}{S_{2in}}\right]e^{-k_2 t} + \left[\frac{k_1}{k_2 - k_1}\frac{S_{1in}}{S_{2in}}\right]e^{-k_1 t}$$

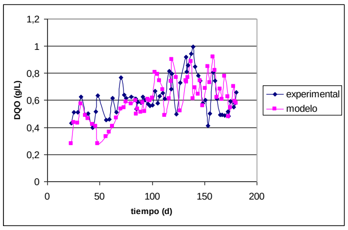
entonces

$$\frac{\overline{S_1}}{S_{1in}} = G(k_1)$$

$$G(s) = \left(\frac{1}{1 + \frac{\tau}{N}s}\right)^N$$

$$\frac{\overline{S_2}}{S_{2in}} = AG(k_1) + [1 - A]G(k_2)$$

con $A = \frac{k_1}{k_2 - k_1}\frac{S_{1in}}{S_{2in}}$



***N* = 1.0098**

k_{1o}	0.0038 $(d.kgSSV)^{-1}$
k_{2o}	0.0014 $(d.kgSSV)^{-1}$