BIODEGRADATION OF BTEX-CONTAMINATED GAS IN A SPARGED SHALLOW LIQUID REACTOR

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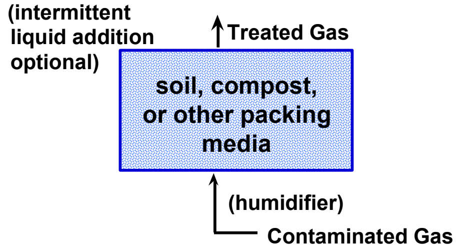
- Sources of contaminated gases
  - industrial emissions
  - SVE off-gas from site-remediation

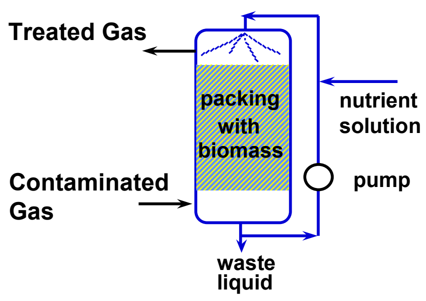
- Conventional gas treatment methods
  - activated carbon
  - incineration

- Biological gas treatment reactors

BIOFILTER

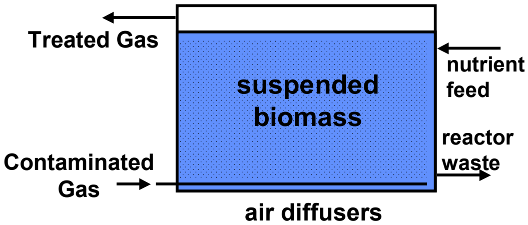


BIOTRICKLING FILTER



- BTEX treatment demonstrated
- Excess biogrowth affects reliability
  - –potential media plugging
  - –potential gas short circuiting

SPARGED SHALLOW REACTOR



DESIGN AND OPERATION OF A SPARGED REACTOR

- What liquid depth is required?
- What operating SRT ?

OBJECTIVES

- Investigate the ability to achieve high gas treatment efficiency for BTEX compounds
- Investigate the effect of operating SRT on gas treatment efficiency

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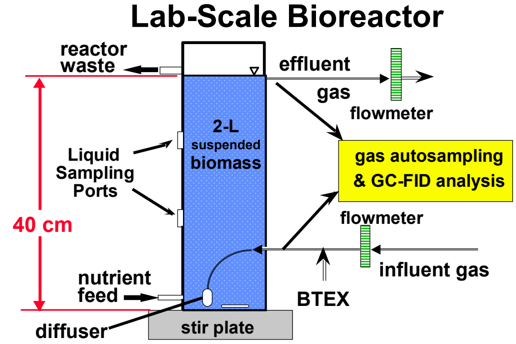
DEVELOP A MASS TRANSFER & BIODEGRADATION MODEL

- BTEX Mass Transfer Experiments
  - Henry's coefficient
  - relate BTEX & oxygen mass transfer coefficients (Kla)

- BTEX Biodegradation Kinetics
  - Michaelis Menten model for individual compounds (K & Ks)
  - effect of mixtures

  → competitive inhibition model

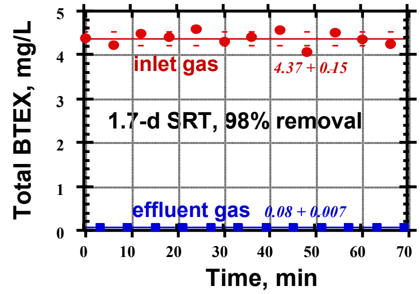
Lab-Scale Bioreactor



Key Operating Conditions

- Liquid Depth = 40 cm
- Liquid Volume = 2 L
- SRT = 1.7, 2.7, 9.2 days
- Oxygen Kla = 0.1 to 0.2 min^{-1}
- Temperature = 20 to 24 °C
- Qg / A = 4 to 8 cm/min
- Inlet Gas BTEX 2.3 - 4.3 mg/L

BTEX Removal Over Analytic Period



Average LongTerm Gas Treatment Results

SRT, days	Load, mg/L-hr	VSS mg/L	BTEX, mg/L Inlet	BTEX, mg/L Effluent
1.7	15.3	444	4.32	0.01
2.7	16.8	756	2.92	<0.01
9.2	14.9	1327	2.29	0.04

BTEX Not Dectected in Effluent Gas During Many Analysis Periods

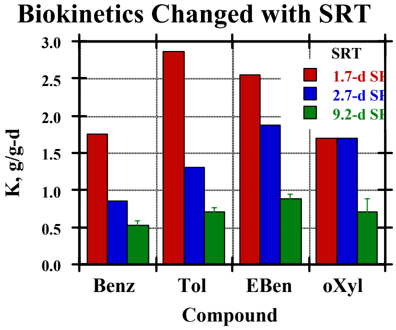
SRT days	Percent Analysis Periods Not Detected			
	Benz	Tol	EthylB	o-Xyl
1.7	86	86	64	86
2.7	100	96	96	100
9.2	72	65	59	70

Gas Treatment Efficiency

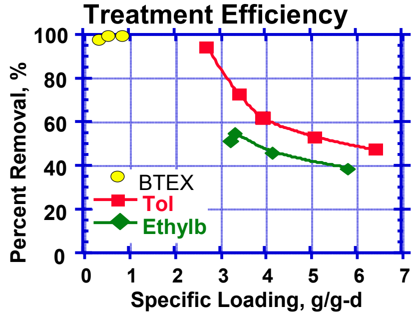
SRT	Average Percent Removal			
days	Benz	Tol	Ethylb	o-Xyl
1.7	99	99	99	99
2.7	99	99	98	98
9.2	98	97	97	98

* non detected effluent gas concentrations were set at the method detection limit (0.01 mg/L)

Biokinetics Changed with SRT



Effect of Specific Loading on Gas Treatment Efficiency



MODEL

Steady State Gas Treatment

Cg-out = Cg-in (exp R) + H Cl (1- exp R)

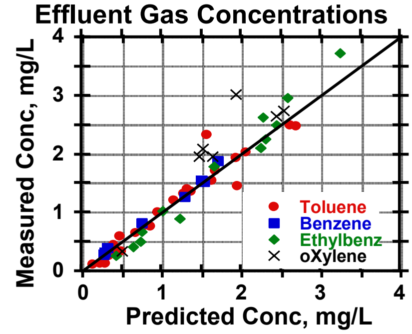
where: $R = - \frac{Vl \ Kla}{Qg \ H}$

The VOC concentration in the reactor liquid is a function of the biodegradation kinetics:

$$\frac{(Cg\text{-}in - Cg\text{-}out)\ Qg}{Vl} = \frac{K \ Cl \ X}{Ks \ I + Cl}$$

I = inhibition constant
= 1 + Cl-b/Ks-b + Cl-c/Ks-c + ...

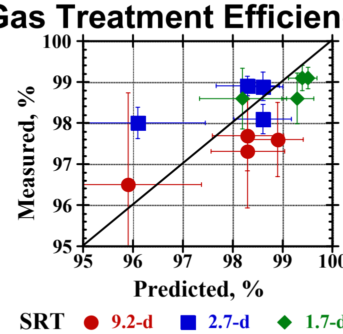
Measured versus Predicted Effluent Gas Concentrations



Steady-State Reactor Performance vs. Model Predictions

- Using the two equations, solved simultaneously for Cg-out and Cl
- Predicted liquid concentrations ranged from 0.01 to 0.03 mg/L for each BTEX compound, which agreed with measured values (< 0.05 mg/L detection limit)
- Predicted removal efficiencies agreed well with measured values

Gas Treatment Efficiency



When Cl is very low…

Cg-out = Cg-in (exp R) + ~~H Cl (1- exp R)~~

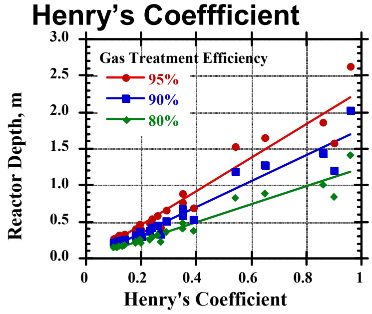
where: $R = - \dfrac{Vl\ Kla}{Qg\ H}$

performance is controlled by mass transfer

When Gas Treatment Efficiency is Not Biodegradation Limited, Design Reactor Depth Using:

$$\text{Depth} = \frac{-\ln(\text{Cg-out} / \text{Cg-in}) * \text{Qg/A} * \text{H}}{\text{Kla}}$$

Required Reactor Depth Related to Henry's Coeffficient



CONCLUSIONS

- High treatment efficiency (>98%) of a BTEX mixture was achieved
  - 40 cm depth
  - loading 15-17 mg/L-hr
  - SRTs 1.7, 2.7, 9.2 days

CONCLUSIONS

- A mechanistic model including mass transfer & biodegradation accurately predicted reactor performance
- The model can be used to aid full-scale design

CONCLUSIONS

- At all SRTs tested, liquid concentrations of BTEX were minimal, such that gas treatment was mass transfer limited
- For mass transfer limited designs, reactor depth is a function of H, Kla, Qg/A