VOC TREATMENT AND ODOR CONTROL USING A SPARGED SHALLOW BIOREACTOR

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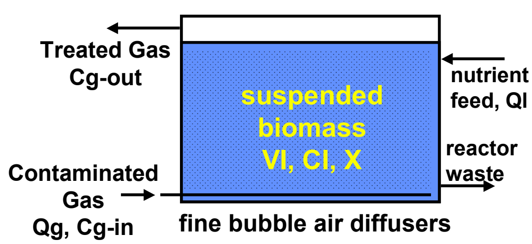
- Contaminated gases
  - odors from municipal wastewater treatment plants (WWTP)
  - VOCs in industrial emissions
  - SVE off-gas from site-remediation

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

Why Use Packing Media?

SPARGED SHALLOW REACTOR



OBJECTIVES

- Evaluate for VOC (BTEX) & odor removal
- Investigate the effect of operating SRT & reactor depth

COMPARE TO A MASS TRANSFER & BIODEGRADATION MODEL

MODEL

Steady State Gas Treatment

$$Cg\text{-}out = Cg\text{-}in\ (\exp R) + H\ Cl\ (1 - \exp R)$$

where: $$R = \frac{-\,Kla\ D}{H\ (Qg/A)}$$

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

$$Cl = \frac{Ks\ (1 + b\ SRT)}{SRT\ (YK - b) - 1}$$

$$SRT = \frac{Vl}{Ql}$$

Select SRT so Cl is very low…

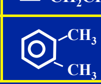
$$Cg\text{-}out = Cg\text{-}in\ (\exp R) + H\ Cl\ (1 - \exp R)$$

performance is controlled by mass transfer

Depth is related to percent removal for mass transfer limited conditions:

$$Depth = \frac{-\ln\ (1 - \%remov / 100)\ H\ Qg/A}{Kla}$$

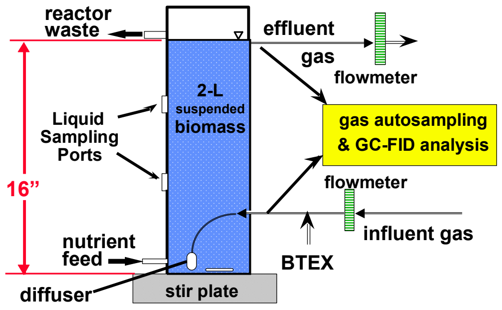
COMPOUNDS STUDIED

VOC (BTEX)	Structure	Henry's @ 25°C, L/L
Benzene		0.23
Toluene		0.27
Ethylbenz		0.33
o-Xylene		0.21

BTEX Studies

- Reactor Performance
- Mass Transfer Experiments
  - Henry's coefficient
  - relate BTEX & O_2 mass transfer (Kla)
- Biodegradation Kinetics
  - Michaelis Menten for individual compounds (K & Ks) & mixture effects

Lab-Scale Bioreactor



Key Operating Conditions

- Liquid Depth = 16 inches
- Liquid Volume = 2 L
- SRT = 1.7, 2.7, 9.2 days
- Oxygen Kla = 6 to 12 hr^{-1}
- Temperature = 20 to 24 °C
- Qg / A = 0.13 to 0.26 ft^3/ft^2-min
- Inlet Gas BTEX 2.3 - 4.3 mg/L

Average LongTerm Gas Treatment Results

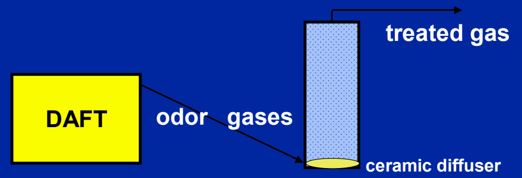
			BTEX, mg/L		% non-
SRT, days	Load, mg/L-hr	VSS mg/L	Inlet	Effl	dect in effl gas
1.7	15.3	444	4.32	0.01	80
2.7	16.8	756	2.92	<0.01	98
9.2	14.9	1327	2.29	0.04	66

Model also predicted low steady-state effluent BTEX concentrations (0.01 - 0.03 mg/L)

Odor Treatment at a Municipal WWTP

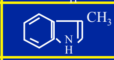
- oxygen transfer in clean water (Kla)
- long term odor compound removal

Gas Treatment Reactor



- Liquid 4.3 ft deep, Column 7.5 inches dia.
- Qg/A = 3.1 ft^3/ft^2-min, Oxygen Kla 96 hr^{-1}
- SRT 123 days, Temperature 11 to 22°C

COMPOUNDS STUDIED

Odor Compound	Structure	Henry's @ 25°C, L/L
Ammonia	NH_3	0.0025
Hydrogen Sulfide	H_2S	0.39
Indole		0.006
Skatole		0.055
Methyl Mercaptan	CH_3SH	0.13

Average Treatment Results for Odor Compounds over 2 months

	H_2S	Amines	NH_3	R-SH
Influent Gas, ppm-v	2.7	0.6	0.2	0.3
Effluent Gas, ppm-v	<0.1	<0.1	<0.1	<0.1

* Detection limits 0.1 ppm-v for odor compounds

Effluent odor compound concs below detection at lower liquid depths

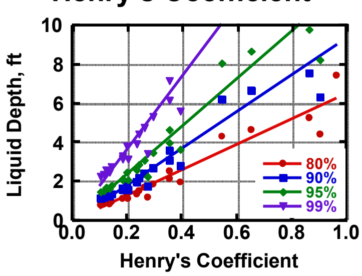
Liquid Depth	Influent Gas Conc, ppm-v				Effluent Concs, ppm-v
	H_2S	Amines	NH_3	R-SH	
4' 2"	4.0	0.1	0.1	0.4	<0.1
3' 8"	2.0	0.3	0.3	0.3	<0.1
3' 2"	1.8	0.2	0.3	0.3	<0.1
2' 7"	5.0	0.2	0.2	0.4	<0.1
2' 0"	4.0	0.1	0.1	0.5	<0.1

Modeled Odor Removal

- **Ammonia:**
  - H = 0.0025 L/L
  - correct Kla for gas film resistance
  - lit. values for nitrification kinetics

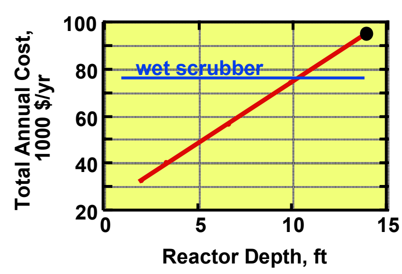
>99% removal at 3 to 12 inch liquid depths

Required Reactor Depth Related to Henry's Coefficient



Odor Treatment Cost Related to Reactor Depth (2200 cfm)

(Bowker & Assoc., Inc. Consulting Engineers, NEWEA Journal, Nov. 1996)



CONCLUSIONS

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

- Odor compounds were removed to below detection limits (0.1 ppm-v)
  - 2 mo. at 4’ 2” depth
  - short term at 2’ to 4’ 2” depth
  - ave loading approx. 0.22 mg/L-hr

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

- For mass transfer limited operation, reactor depth is a function of H, Kla, Qg/A
- Treatment costs in sparged, suspended growth reactors are proportional to liquid depth

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