Hybrid Bioreactors
Cost Saving Processes
For Decontamination of Water and Air

Jeffrey L. Boles and Johnny R. Gamble

Tennessee Valley Authority
Energy Research and Technology Applications
Bioreactors

- Microbial decontamination of liquids

Biofilters

- Microbial decontamination of gases
Applications

- Animal Feed Houses
- Baking
- Chemical Processing
- Composting
- Fiberboard Production
- Fish Processing
- Food Production
- Groundwater/Wastewater
- Meatpacking
- Metalworking
- Municipal Waste
- Painting and Coating
- Paint Stripping
- Petroleum Refining
- Pulp and Paper Mills
- Printing
- Rubber Production
- Soil Vapor Extraction
Conventional Methods

- Stripping creates air pollution
- Sorption methods transfer pollutants
- Incineration generates toxic products
- Generate secondary waste streams
- High costs at low concentrations
Bioreactors/Biofilters

- Microorganisms destroy pollutants
- No secondary waste streams
- Economical at low concentrations
- Simple operation, low maintenance
- Automatic operation, minimal labor
Pollutants Destroyed

Groundwater
- Perchloroethylene
- Trichloroethylene
- Dichloroethylene
- Vinyl Chloride
- MTBE, BTEX
- VOCs

Coating/Stripping
- Styrene
- Acetone
- Toluene
- Xylenes
- Methyl Ethyl Ketone
- Methyl Isobutyl Ketone
- Butyl Acetate
- Methyl Alcohol
- Methylene Chloride

Wastewater
- VOCs
- Hydrogen Sulfide
- Ammonia
- Mercaptans
- Amines
- Odors

Rayon/Fibers
- Carbon Disulfide
# TVA Demonstrations

<table>
<thead>
<tr>
<th>Location</th>
<th>Application</th>
<th>Contaminants</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANAD, AL</td>
<td>Groundwater</td>
<td>TCE, DCE, VC, MeCl</td>
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<tr>
<td>Murfreesboro, TN</td>
<td>Fiberglass Coatings</td>
<td>Styrene, Acetone, MEK</td>
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<td>Starkville, MS</td>
<td>Swine</td>
<td>H₂S, NH₃, Amines, Mercaptans, Odors</td>
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<tr>
<td>Decatur, AL</td>
<td>Wastewater</td>
<td>H₂S, Mercaptans, Odors</td>
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<tr>
<td>Florence, AL</td>
<td>Wastewater</td>
<td>H₂S, Mercaptans, Odors</td>
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<td>Bankhead NF, AL</td>
<td>Vault Toilet</td>
<td>H₂S, NH₃, Odors</td>
</tr>
<tr>
<td>Muscle Shoals, AL</td>
<td>Groundwater Wastewater</td>
<td>TCE, MTBE, VOCs . . .</td>
</tr>
</tbody>
</table>
Biofilter (Gas Treatment)

Compost Pine Bark Microbes

Clean Air

Contaminated Air
Contaminated Water → Bioreactor (Liquid Phase) → Microorganisms and Support Matrix → Clean Water
Cometabolic Bioreactors

- Chlorinated compounds (e.g. TCE)
- Pollutants are not consumed
- Utilize primary substrate (food)
- Enzymatic contaminant destruction
- Cyclical process for efficiency
Polluted Air Compost Pine Bark Microbes

Contaminated Groundwater

Destruction of TCE at ANAD

Propane

Clean Air

Biofilter

Compost Pine Bark Microbes

Surface Water

Carbon Filter

Groundwater w/o TCE/DCE

Air

Air Stripper
Hybrid Bioreactors

Contaminated Water

Nutrients

Packing with Microbes

Clean Air

Decontaminated Water
Hybrid Bioreactors

- TCE, MTBE, VOCs, fuels, odors
- Single-step water/air cleanup
- Remove and destroy toxics
- Dramatic cost savings
- No contaminated off-gases
- No secondary waste streams
- Auto operation, minimal labor
Hybrid Costs < 10% of SF Sites

Multiple Treatment Systems
(e.g. Stripping + GAC Adsorption)

Treatment Costs, $/Kgal water

C-M HYBRID
D-M HYBRID
DOE Sites - Various
French, Ltd., TX
Firestone, CA
Old Mill, OH
Sol Lynn, TX
U.S. DOE KC, MO
Keefe, NH
Intersil, CA
Site A, NY
Amoco, MI
Bofors Nobel, MI
Baird and McGuire, MA
Sylvester/Gilson Rd, NH
Solv Recov Service, CT
Libby, MT
King of Prussia, NJ
Rapid Decrease in Size/Costs Required

When \( R = L \),
\[
E = 100 \frac{R}{L} = 100\%
\]

Degradation Rate (R)
Size Ratio (S)
Elimination Efficiency (E)

Rapid Decrease in Size/Costs Required
Improvement Over ANAD Biofilter

When \( R = L \),
\[ E = 100 \frac{R}{L} = 100 \]
Increasing Water Concentration

Elimination Efficiency, $E$

Load, $L$

Degradation Rate, $R$

Water Rate = 7 gpm per 1000 ft$^3$ Packing
Decreasing Size and Costs

Cometabolic Hybrid Bioreactor (e.g. TCE)
Direct-Metabolic Bioreactors

- Pollutants directly consumed (food)
- BTEX, VOCs, fuel components
- Some chlorinated compounds
- Ammonia, hydrogen sulfide, odors
- High efficiency, low cost
Influent Water Concentration = 8 mg/L
(Benzene: 4 mg/L, Toluene: 4 mg/L)

Rapid Performance Improvement
Decreasing Size and Costs

Influent Water Concentration = 8 mg/L
(Benzene: 4 mg/L, Toluene: 4 mg/L)
Comparing Size and Costs

- Elimination Efficiency, %
  - $E_{VOC}$
  - $E_{TCE}$

Size, ft$^3$ per gpm water

[Diagram showing comparison of size and costs for different efficiencies.]
Advantages

- Dramatic cost savings
- Single-step water/air cleanup
- Remove and destroy toxics
- No contaminated off-gases
- No secondary waste streams
- Variety of contaminants
- Auto operation, minimal labor