Development of a Novel Off-line Enricher Reactor Process Scheme for the Activated Sludge Degradation of Hazardous Wastes

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Outline

1. Enricher Reactor Concept
2. Previous Work
3. Current Studies
4. Inducer Compounds
5. Future Directions
PREVIEW

1. Enricher Reactor Concept
2. Original Work
3. Process Improvement
4. Inducer Compounds
5. Future Directions
Activate Sludge Process

Wastewater

Volatilization

Waste Sludge

Treated Effluent
Process Modifications

- Complete Mixing
- Conventional or Plug Flow
- Extended Aeration
- Step Feed
- Contact Stabilization
- High Purity Oxygen
Enricher Reactor System

- Enrichment Substrates
- Wastewater
- Enzymes
- Cells
- Sequencing Batch Reactors, functioning as enricher reactors
- Volatilization
- Waste Sludge
- Treated Effluent
ADVANTAGES

Independence of Enricher Reactor
- protected from periodic upsets and operating constraints of main reactor
- back-up culture
- optimized growth conditions
- acclimation to volatile compounds
- uncompromised operation

Cost Effectiveness
- utilization of existing infrastructure
- small size
PREVIEW

1. Enricher Reactor Concept
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2,4 XYLENOL ENRICHED REACTOR SYSTEM

(2,4 Xylenol)
Enrichment Substrates

Sequencing Batch Reactor, functioning as an enricher reactor

Cells

Synthetic Wastewater

Volatilization

Degrades phenol, cresols, trimethylphenol and all isomers of Xylenol except 3,5

Treated Effluent

Waste Sludge
2-4 XYLENOL PATHWAY

\[ \text{2,4 Xylenol} \rightarrow \text{CHO} \rightarrow \text{COOH} \rightarrow \text{CHO} \rightarrow \text{COOH} \rightarrow \text{CHO} \rightarrow \text{COOH} \]

**Substances:**
- Protocatechuic Acid
- c-Ketoadipic Acid

**Chemical Structures:**
- 2,4 Xylenol
- Protocatechuic Acid
- c-Ketoadipic Acid
NAPHTHALENE ENRICHER REACTOR SYSTEM

(Salicylate and a trace of Naphthalene or Phenanthrene)
Enrichment Substrates

Sequencing Batch Reactor, functioning as an enricher reactor

Synthetic Wastewater

Cells

Volatilization

Waste Sludge

Treated Effluent

_Degrades naphthalene or phenanthrene, and possibly others_
Degradation Of Naphthalene By A CFSTR Augmented With Cells From An Enricher Reactor

Control (unacclimated)

5.7 ug/L naphthalene (conventional)

5.7 ug/L naphthalene + enricher AS (enriched)
Naphthalene Volatilization Rate from a Typical Wastewater Treatment Plant

![Graph showing the relationship between removal percentage and decay rate (K, 1/h). The graph includes points for degraded and volatilized substances, with calculated points indicated.]
Naphthalene Volatilization Rate from a Laboratory Reactor

Removal (%) vs. Decay Rate (K, 1/h)

- Degraded
- Volatilized
(calculated points)
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MODEL HAZARDOUS COMPOUNDS

AMINO PAH'S

1 - Naphthylamine (1-NA)

9 - Aminophenanthrene (9-AP)
LABORATORY REACTORS

12.2 liter Aeration Zone

Effluent Zone

1.5 liter Settling Zone

Sludge Blanket

pH probe

SIDE

Air

Feed

TOP

END

Sampling Port

Plexiglass Construction

Air

Feed

Air

Effluent
Lab Reactor
Phase I - Acclimation and Enrichment

1. Salicylic acid media
2. Deep purple culture
3. Isolates
Removal of 50 mg/L 1-NA in an Enricher Reactor

- Control (no cells)
- Active - supernatant
- Active - cell adsorbed
Degradation of Various Concentrations in an Enricher Reactor

Degradation Rate (mg/h) vs. Initial Concentration (mg/L)

- Degradation rate increases with increasing initial concentration up to a certain point.
- Beyond that point, the degradation rate decreases as the concentration continues to increase.

University of California, Los Angeles
Phase II - Bioaugmentation

1. Steady-state
2. Batch experiments
3. Bioaugmentation level studies
<table>
<thead>
<tr>
<th>SUBSTRATES</th>
<th>CFSTR's</th>
<th>SBR's</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>No target compounds</td>
<td></td>
</tr>
<tr>
<td>Conventional I</td>
<td>1-NA (1 mg/L)</td>
<td>E1 1-NA (150 mg/L)</td>
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<tr>
<td>Conventional II</td>
<td>9-AP (0.1 mg/L)</td>
<td>E2 9-AP (20 mg/L)</td>
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<tr>
<td>Enriched I</td>
<td>1-NA (1mg/L) + 2% inoculum E1</td>
<td></td>
</tr>
<tr>
<td>Enriched II</td>
<td>9-AP (0.1 mg/L) + 2% inoculum E2</td>
<td></td>
</tr>
</tbody>
</table>
LABORATORY ENRICHER REACTOR SET-UP

Control

Conventional
1-NA 1 mg/L

Conventional
9-AP 0.1 mg/L

Enriched I
1-NA 1 mg/L

Enriched II
9-AP 0.1 mg/L

Salicylic acid, Yeast extract, and nutrients

1-NA 150 mg/L

9-AP

0.1 mg/L

Bacto peptone, Beef extract, Yeast extract, and nutrients

9-AP 20 mg/L
Batch Biodegradation Test (1 mg/L)
Batch Biodegradation Test (3 mg/L)

CONCENTRATION (mg/L)

TIME (hr)

Unacclimated

Enriched

Conventional
CFSTR RESPONSE TO A STEP LOADING INCREASE

Influent

Conventional

Enriched 6%

Time (d)

Concentration (mg/L)
BATCH BIOAUGMENTATION LEVEL TEST (10 mg/L)

TIME TO REACH DETECTION LIMITS (hr)

0 12 24 36 48

0 10 20 50 100

BIOAUGMENTATION LEVEL (%)
LABORATORY BIOAUGMENTATION LEVEL SET-UP

- Bacto peptone, Beef extract, Yeast extract, and nutrients
- Salicylic acid, Yeast extract, and nutrients

Control
- 1-NA 1 mg/L

Conv
- 1-NA 1 mg/L

E-1%
- 1-NA 1 mg/L

E-2%
- 1-NA 1 mg/L

E-4%
- 1-NA 1 mg/L

E-8%
- 1-NA 1 mg/L

E-16%
- 1-NA 1 mg/L

1-NA 150 mg/L
PREVIEW

1. *Enricher Reactor Concept*

2. *Original Work*

3. *Process Improvement*

4. *Inducer Compounds*

5. *Future Directions*
INDUCER COMPOUNDS

• Use compounds other than 1 NA to induce 1 NA biodegradation
• Use these compounds in the enricher reactor
• Select compounds similar to the target compound (1 NA)
• Hopefully less hazardous and inexpensive
• Hopefully easier to analyze and manage
SELECTED INDUCER COMPOUNDS

- 1-acetate-naphthalene (1AN)
- 1-naphthalene-sulfonic acid (1SN)
- 1-naphthoic acid (1NO)
- 1-chloro-naphthalene (1CN)
- Gentistic acid (GA)
Culture Growth

Cultures were grown on each compound in fill and draw reactors.

Maximum growth rates were determined for comparisons later.

Tested later with 1 NA.
Acclimation of 1-NO

![Graph showing the acclimation of 1-NO over time with concentration on the y-axis and time on the x-axis. The graph includes two lines: one for 1NO ER and another for 1NO ER adsorbed.](image)
Acclimation of 1 SN

![Graph showing concentration of 1SN ER and 1SN ER adsorbed over time.](image-url)
1 NA Biodegradation

- 1NA ER
- 1NA ER adsorbed

CONCENTRATION (mg/L)

TIME (hours)
Acclimation of 1 AN

CONCENTRATION (mg/L) vs. TIME (hours)

- 1AN ER
- 1AN ER adsorbed
Acclimation of GA

CONCENTRATION (mg/L)

TIME (hours)

GA ER

GA ER adsorbed
Disappearance of 1 NA Comparison

![Graph showing time vs. concentration for different samples.](image)
DIRECTIONS

Process Engineering
- show improvement with bioaugmentation level
- scale-up design (kinetics)
- generalizations

Microbiology
- health of cells
- sustainability of activity
- substrate composition
- optimum enrichment cultures
ACKNOWLEDGEMENTS

• US National Science Foundation
• California TSR&TP
• All my former and current graduate students