Treatment of N-Nitrosodimethylamine in Groundwater Using a Fluidized Bed Bioreactor (FBR)

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INTRODUCTION

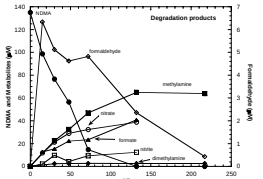
- **N-nitrosodimethylamine (NDMA) is a byproduct of liquid rocket fuels, disinfection processes, and some IX resins.**
- **It is completely miscible in water with low volatility.**
- **NDMA is a known carcinogen. California has a 10 ng/L action level and a 3 ng/L public health goal.**
- **Sites include DOD and NASA facilities and contractors including White Sands Test Facility and Aerojet.**
- **Typical remediation involves pump and treat with UV, but this approach is expensive due to high energy usage.**

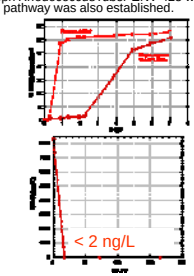
PRIOR RESEARCH

Pure Culture Studies

- Degradation of NDMA using the propanotroph *Rhodococcus ruber* ENV 425 was successfully demonstrated to < 2 ng/L. The pathway was also established.

Biodegradation of NDMA by *R. ruber* ENV425 (propane monooxygenase)

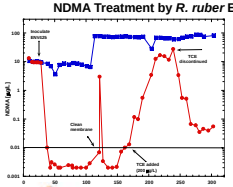


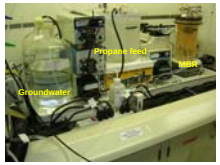


Laboratory Membrane Bioreactor (MBR)

- NDMA was cometabolized in a membrane bioreactor (MBR) from typical groundwater concentrations (i.e., 1-80 µg/L) to low part-per-trillion levels. High levels of TCE inhibited performance.
- *R. ruber* was shown to develop an extensive biofilm that may be highly suitable for optimal performance in a fluidized bed bioreactor (FBR).

NDMA Treatment by *R. ruber* ENV425 in a Laboratory MBR





PROJECT OBJECTIVES

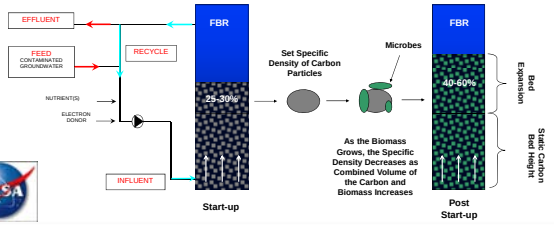
- To demonstrate and validate the use, performance, and cost-effectiveness of an FBR for the treatment on NDMA laden water to low part-per-trillion levels.
- The success of the demonstration is contingent on validating the performance at a system hydraulic residence time (HRT) of less than one hour while achieving effective NDMA removal.
- A six month FBR bench-test was conducted using water that mimics the WSTF groundwater contaminated with NDMA to determine pilot-scale feasibility. This study included:
  - Establishing ENV425 NDMA removal kinetics in a laboratory FBR.
  - Evaluation of short-term feed and electrical pump failure/system restart scenarios.
  - Co-contaminant removal performance and effects on NDMA removal performance
- Pilot-study at WSTF in field to follow based on effective bench-scale study

Existing Full-Scale FBR Installations (50-5000 GPM)

FUNDAMENTALS OF FBR OPERATION

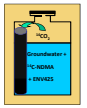
- The FBR is a bottom loaded system.
- The settled granular activated carbon bed is measured and then hydraulically expanded approximately 30%.
- Contaminated feed water is added to a water recycle line along with an electron donor (propane), oxygen, and a nutrient solution (phosphate/urea blend).
- Per a volumetric balance, the volume of water entering at the feed exits the top of the FBR from the effluent line.
- As the propane is degraded and the NDMA is cometabolized, biomass attaches onto the carbon and the bed expands to 40-60% the settled bed height. Excessive bed growth is limited by biomass separators.

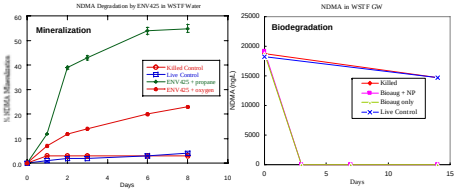
FBR Fundamentals



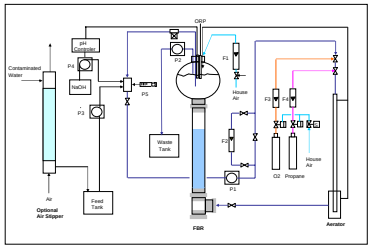
MICROCOSM STUDIES USING WSTF GROUNDWATER

WSTF Analyte	Groundwater Result s (µg/L)
Nitrosodimethylamine (NDMA)	8.1-18.7
Trichloroethylene (TCE)	2.5-3.5
CFC-21	2.3-4.7
CFC-11	206-240
Freon-113	51.2-154





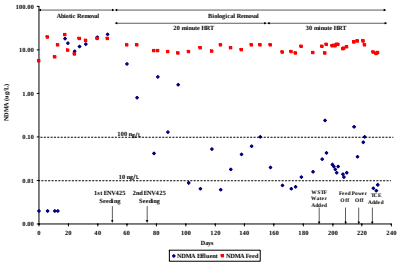
FBR BENCH-SCALE STUDY WITH SIMULATED and REAL WSTF WATER



Reactor Design Criteria

- Diameter = 5 cm
- Settled Bed Height = 40 cm
- Hydraulically Expanded Bed Height = 52 cm
- Expanded Bed Volume = 1350 ml
- Recirculation Flow = 1200 ml/min
- Feed Flow = 65-70 ml/min
- Feed NDMA Concentration = 10-20 µg/L
- HRT = 20 min
- Propane Flow = 1 ml/min (1.45 mg/min as TOC)
- Oxygen Flow = 3-7 ml/min (4.0-9.2 mg/min)

NDMA REMOVAL IN THE BENCH-SCALE FBR



WSTF FBR PILOT SYSTEM – START-UP EXPECTED 12/2011

SUMMARY AND CONCLUSIONS

- **Initial microcosm studies demonstrated that ENV425 could effectively degrade NDMA in the WSTF groundwater.**
- **The presence of TCE, CFC-11, CFC-21, and Freon-113 ar ug/L concentrations did not inhibit the NDMA treatment by ENV425 during the microcosm studies.**
- **After bioaugmenting the bench FBR with ENV425, biological treatment of NDMA was clearly evident. FBR bed height increased concurrently.**
- **Treatment of 10-20 µg/L concentrations of NDMA was consistently demonstrated in the bench-scale FBR to less than 100 ng/L. NDMA was treated to less than 10 ng/L with optimized conditions:**
  - ***A 20-30 minute hydraulic residence time***
  - ***An oxygen addition rate of 6-7 ml/min (7.9-9.2 mg/min)***
  - ***A propane addition rate of 0.6-0.8 ml/min (0.9-1.2 mg C/min)***
  - ***A diammonium phosphate addition rate of 0.58 ml/min at 88 mg/L***
  - ***A urea addition rate 0.58 ml/min at 176 mg/L***
- **Co-contaminant removal of NDMA and TCE was possible. No inhibition of NDMA treatment observed when TCE present at site concentrations (low ug/L).**
- **An FBR pilot-scale study is scheduled at WSTF Mid-Plume Treatment Facility in 2011-2012. The FBR is constructed and awaiting start-up.**

- **We wish to thank ESTCP for supporting this research.**