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EMSI

Full-Scale Treatment of 1,4-Dioxane Using a Bioreactor

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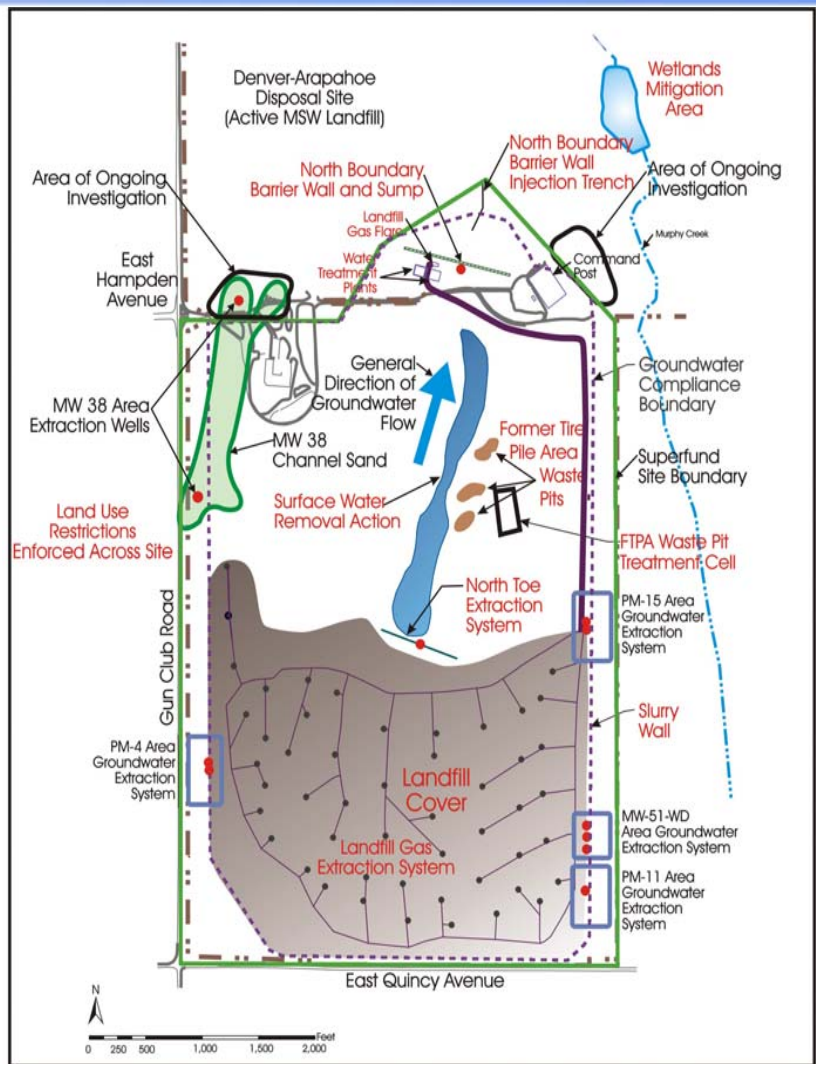
BACKGROUND

- Lowry Landfill Superfund Site
  - Located just outside Denver, Colorado
  - A 480 acre industrial and municipal landfill from the mid-1960's to 1980
  - Estimated 138 million gallons of liquid industrial wastes disposed into unlined pits until 1980
  - Placed on the Superfund list in 1984
  - Record of Decision lodged in 1994
    - Containment of groundwater is primary objective

SITE MAP

- Water Treatment Plant (WTP) to treat recovered groundwater
- Two primary waste streams
  - North Boundary Barrier Wall (NBBW)
    - 7 to 10 gpm
    - Relatively few organics
  - North Toe Extraction System (NTES)
    - 0.5-3 gpm
    - Flowrate determined by trench level
    - High concentration of organics



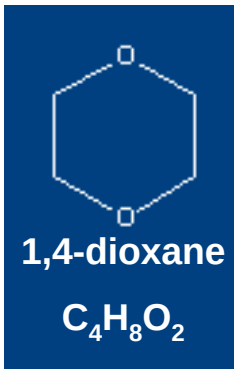
OPERATIONS

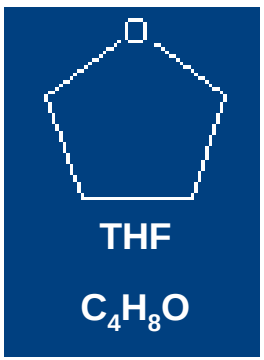
- WTP Pre-treats extracted groundwater prior to discharging to the Denver Metro Water Reclamation Facility
- Treatment includes:
  - Equalization
  - Chemical Softening
  - pH Adjustment
  - Bag Filtration
  - UV/Oxidation
  - Activated Carbon

PERFORMANCE

- Treatment train cannot remove 1,4-dioxane to below permit (2.0 ppm) due to poor UV transmittance, hydroxyl scavenging with NTES waters, and poor sorption on GAC
- Other permit parameters can be met by GAC alone
- Evaluated a number of technologies:
  - Chemical precipitation (to remove UV-Oxidation interferences)
  - Additional Advance Oxidation Processes
  - Thermal Treatment
  - Biological treatment

LITERATURE SEARCH

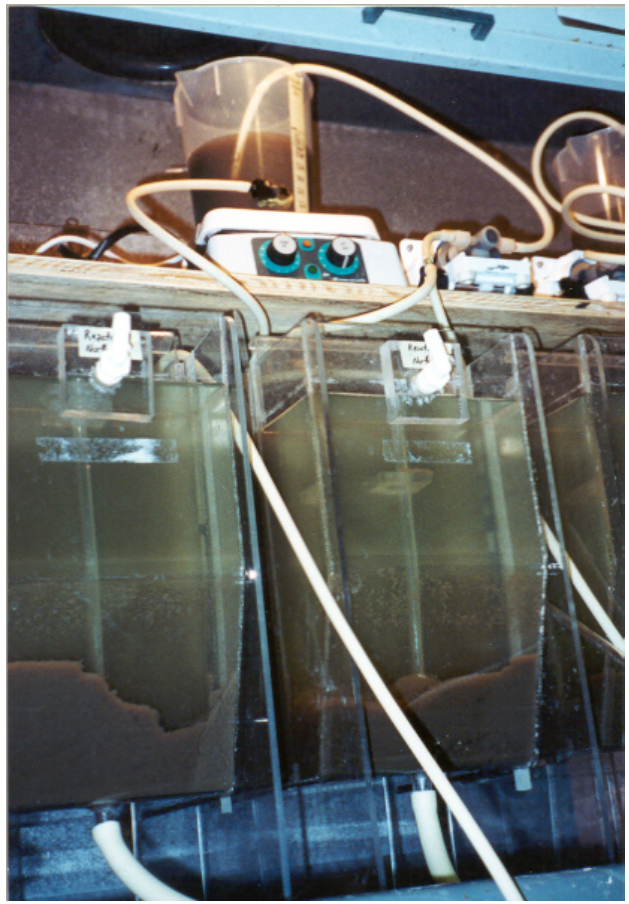




- Clemson University
  - Reactors operated at 35°C
  - Attached growth bio-reactor
  - 1,4-dioxane removal as sole substrate
  - Reaction efficiency decreased sharply with temperature
- NC State
  - Reactors operated at 35°C
  - Used RBC for seed reactor, performed batch tests with seed
  - 1,4-dioxane removal as cometabolite with Tetrahydrofuran (THF)
  - 1,4-dioxane and THF are structural analogues
  - THF acts as a competitive inhibitor of 1,4-dioxane degradation
  - Reaction rates decreased sharply with temperature

BENCH STUDY

- Two feeds tested:
  - NTES
  - 30% NTES, 70% NBBW Blend
- Operated at room temperature (18-25^{o}C)
- Blended water showed more favorable results
  - NTES 53-77% 1,4-dioxane/THF reductions
  - Blended 73-88% 1,4-dioxane/THF reductions
- Nitrification was not complete using NTES waters only allowing nitrite accumulation and probable ammonia toxicity



PILOT STUDY

- Parallel 300 Gallon, fixed film, Moving Bed Bio-Reactors (MBBRs)
- Acclimation started September 2002
- Two reactors to study effect of temperature, Reactor 1 @ 25^{o}C and Reactor 2 @ 15^{o}C

STUDY CONCLUSIONS

- Biological degradation of 1,4-dioxane is possible with blended stream
- 1,4-dioxane and THF degradation was promoted by the indigenous bacteria population
- 1,4-dioxane was degraded to greater than 95% efficiency consistently at organic loadings (F/M ratio) of 0.04 to 0.075 g D&T COD/g TS*d
  - F = food as grams of COD equivalent of 1,4-dioxane and THF
  - M = mass of solids on media in reactor
- Reductions occurred in 12 to 15 hours at F/M ratios noted
- Biodegradation of 1,4-dioxane at 15^{o}C was possible but more susceptible to upset conditions
- 1,4-dioxane was not removed by volatilization
- THF was required for 1,4-dioxane degradation
- Instantaneous increases in loadings of 25-percent resulted in 2-3 days decreased 1,4-dioxane degradation efficiency
- Move forward with full-scale biological treatment of 1,4-dixoane

PROCESS WATER CHARACTERISTICS

Parameter	30:70 NTES:NBBW Blend
Flow	1.3–6.0 gpm
1,4-dioxane	13,000-25,000 μg/L
Tetrahydrofuran (THF)	30,000-60,000 μg/L
Total Suspended Solids (TSS)	75-170 mg/L
Ammonia	140-230 mg-N/L
Nitrite	<0.1-1.7 mg-N/L
Nitrate+Nitrite	14-21 mg-N/L

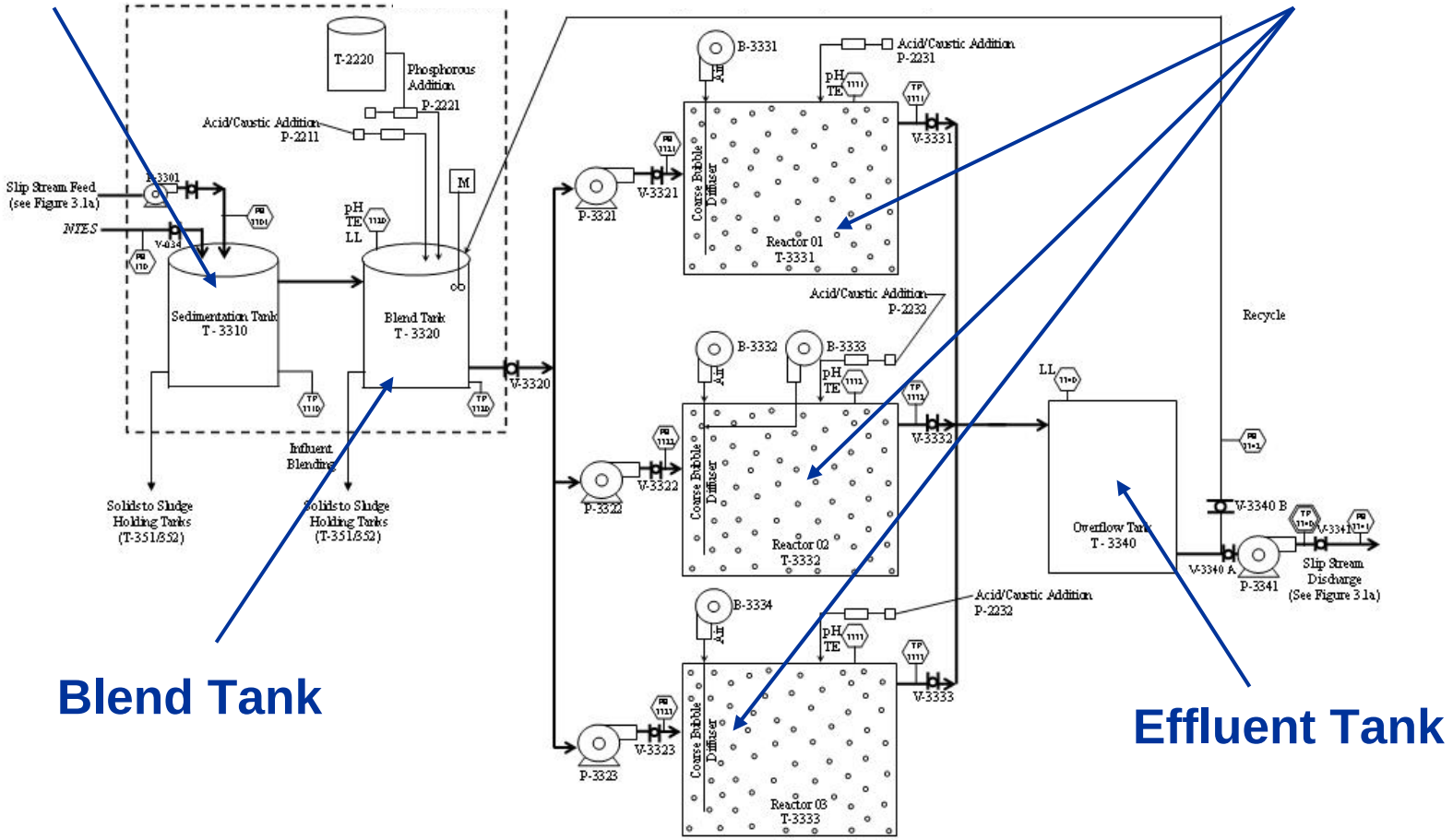
DESIGN AND OPERATION

- Design criteria:
  - Flowrates up to 10 gpm blended flow
  - Effluent water quality < 1,000 μg/L 1,4-dioxane
- Slip-stream from main WTP
- 300 gallon Sedimentation Tank for coarse solids sedimentation
- 300 gallon Blend Tank for blending, pH adjustment, and phosphorous addition
- 3 aerobic, fixed-film, MBBRs
  - 2 x 3,900 gallons; 1 x 5,400 gallons
  - Kaldnes® media used for fixed film growth
  - 32 to 36% of reactor volume filled with media or approximately 8,400 m^2 of surface area
- Coarse bubble diffusers for aeration and mixing

DESIGN AND OPERATION (cont)

Sedimentation Tank

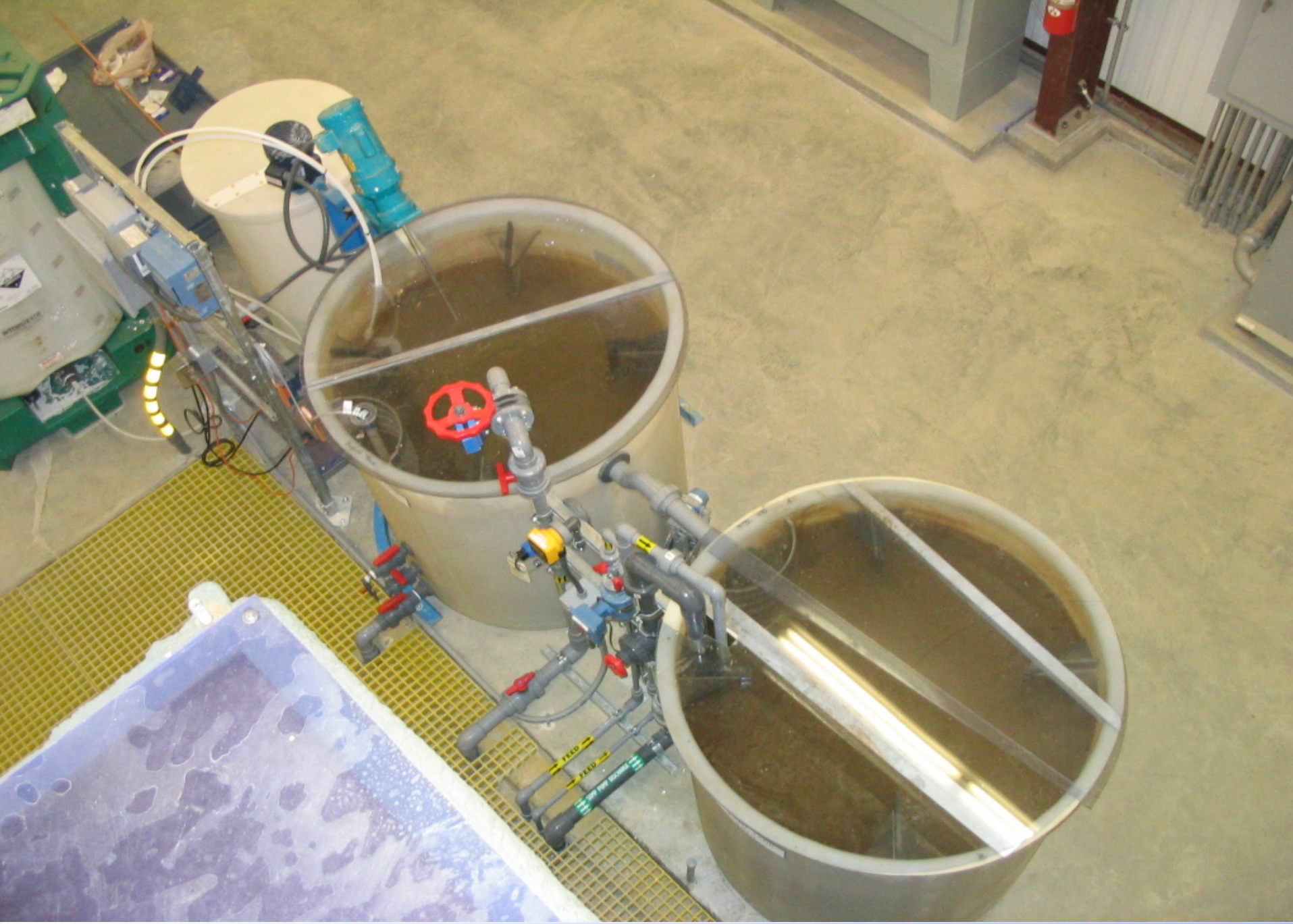
3 MBBRs



Blend Tank

Effluent Tank

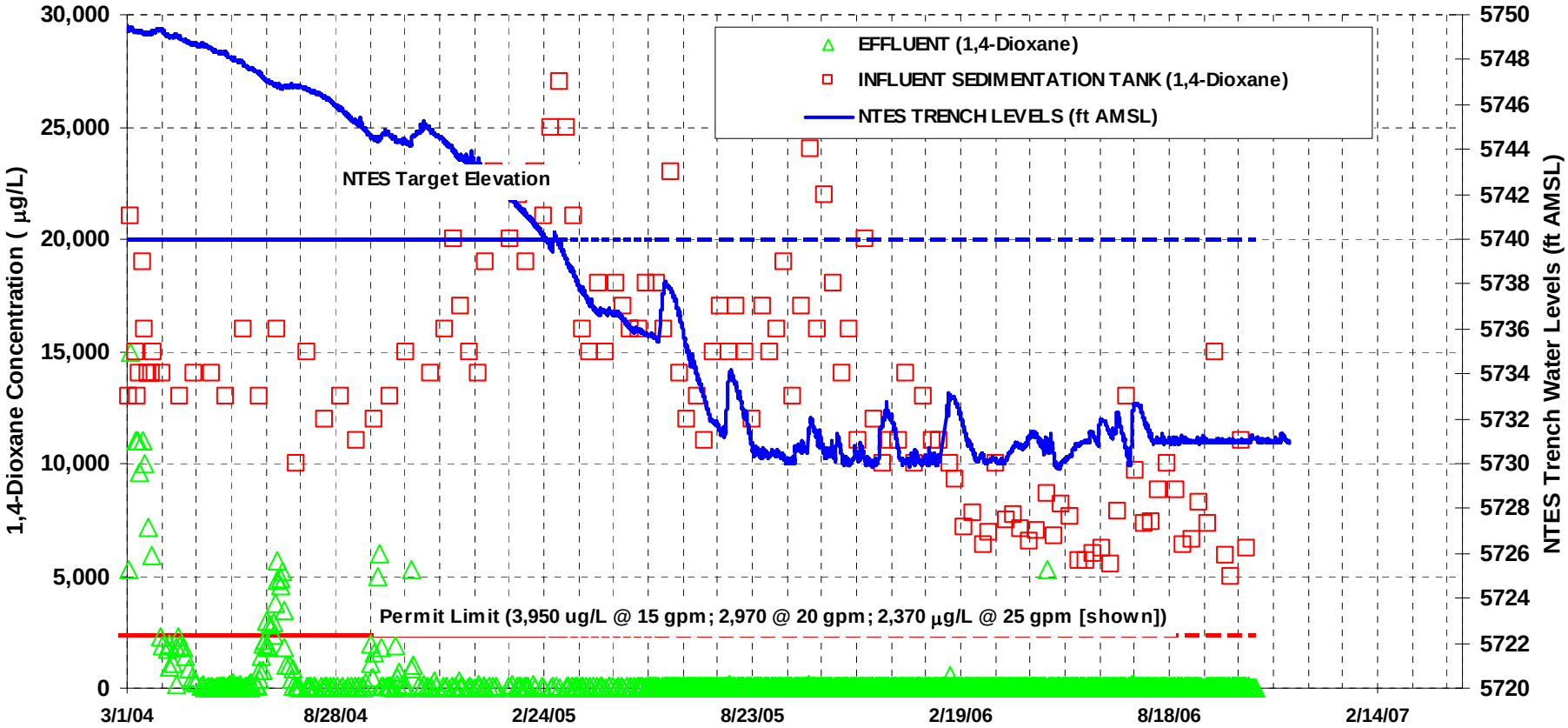

VWGR



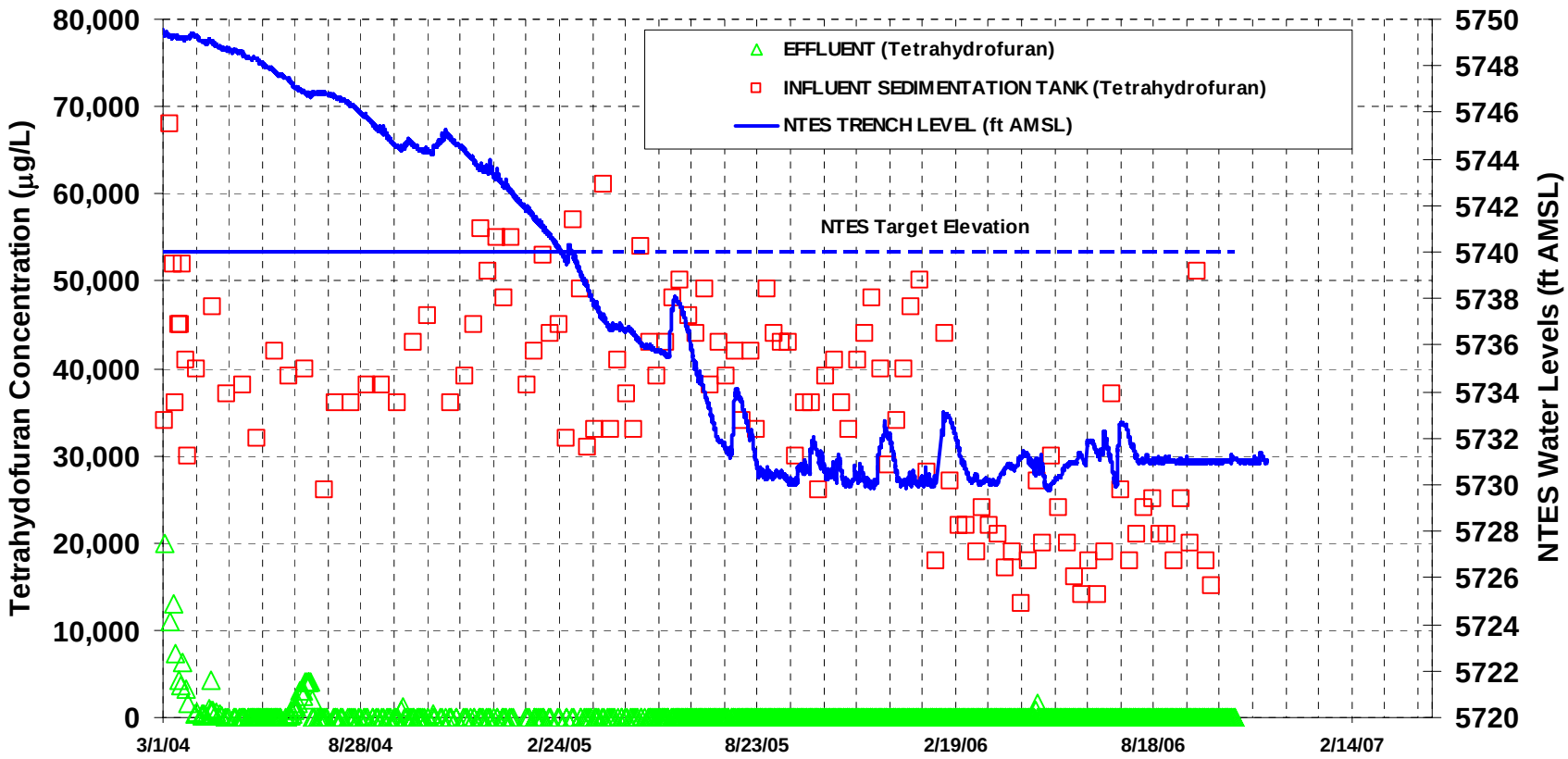
RESULTS

- Acclimation began in March 2004
  - Seeded with indigenous bacteria inherent to the raw NTES stream
  - Low flow-rate (1.3 gpm)
- Transition began in May 2004
  - Flowrates between 2.7 and 6.0 gpm
- Full-Scale operations began in January 2005
  - Maximum flowrate of 6.0 gpm dictated by flowrate from NTES not based on system capability
  - Successful compliance testing

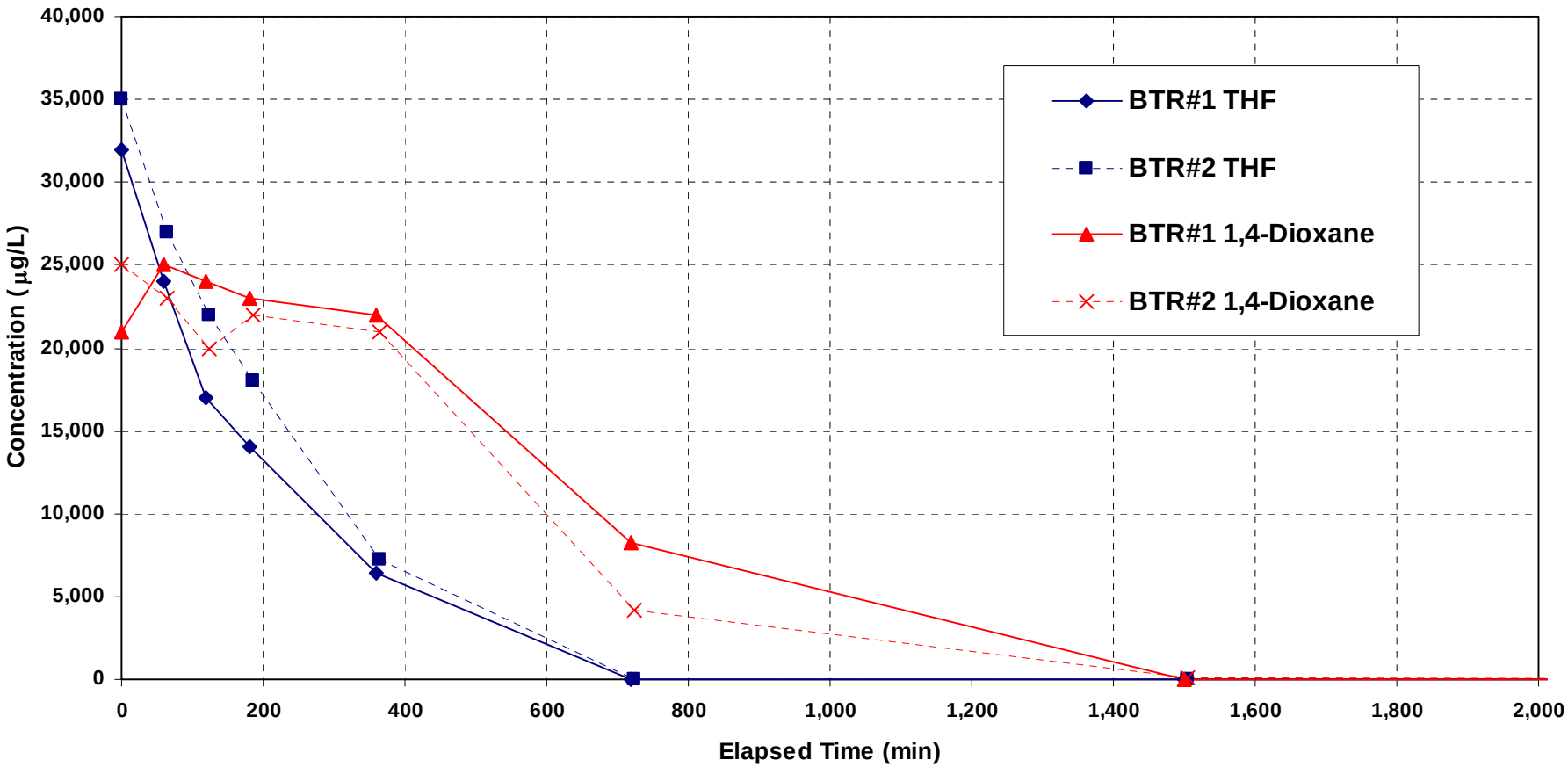
1,4-DIOXANE


EFFLUENT (1,4-Dioxane)
INFLUENT SEDIMENTATION TANK (1,4-Dioxane)
NTES TRENCH LEVELS (ft AMSL)
NTES Target Elevation
Permit Limit (3,950 ug/L @ 15 gpm; 2,970 @ 20 gpm; 2,370 µg/L @ 25 gpm [shown])
1,4-Dioxane Concentration (µg/L)
NTES Trench Water Levels (ft AMSL)
30,000
25,000
20,000
15,000
10,000
5,000
0
5750
5748
5746
5744
5742
5740
5738
5736
5734
5732
5730
5728
5726
5724
5722
5720
3/1/04
8/28/04
2/24/05
8/23/05
2/19/06
8/18/06
2/14/07

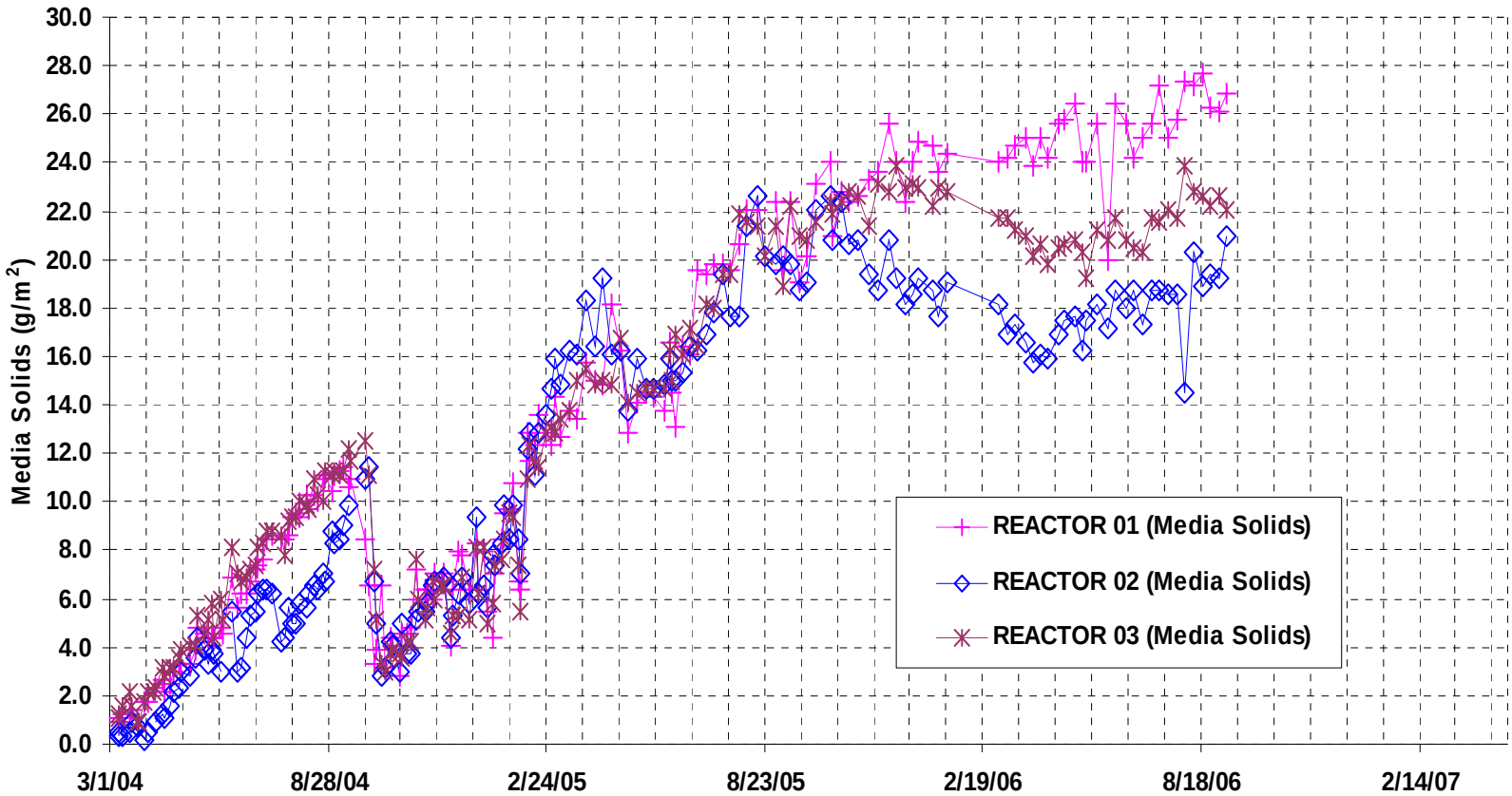
TETRAHYDROFURAN



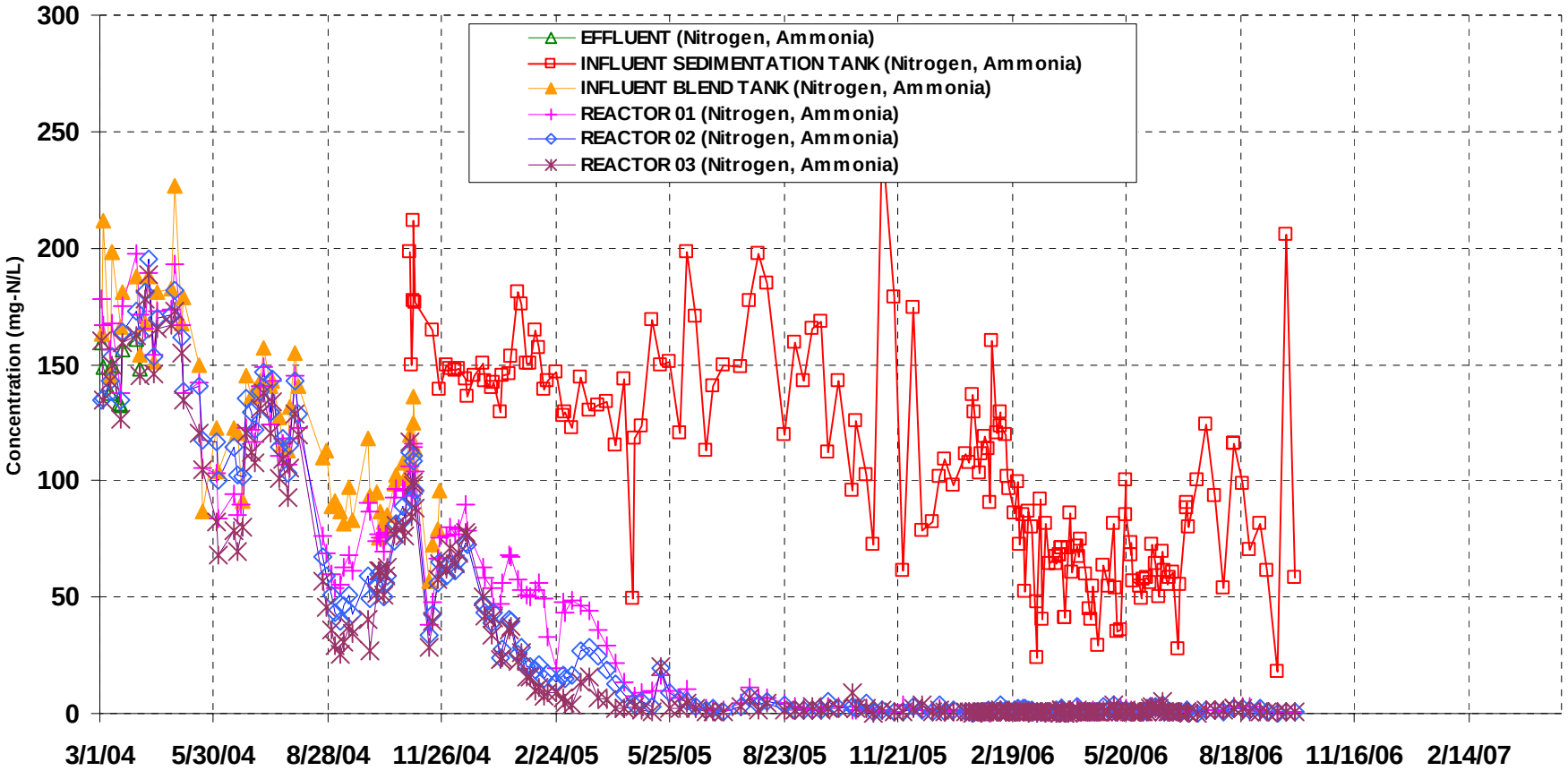
EXAMPLE DEGRADATION PROFILE



MEDIA SOLIDS



AMMONIA


EFFLUENT (Nitrogen, Ammonia)
INFLUENT SEDIMENTATION TANK (Nitrogen, Ammonia)
INFLUENT BLEND TANK (Nitrogen, Ammonia)
REACTOR 01 (Nitrogen, Ammonia)
REACTOR 02 (Nitrogen, Ammonia)
REACTOR 03 (Nitrogen, Ammonia)
Concentration (mg-N/L)
300
250
200
150
100
50
0
3/1/04
5/30/04
8/28/04
11/26/04
2/24/05
5/25/05
8/23/05
11/21/05
2/19/06
5/20/06
8/18/06
11/16/06
2/14/07

CONCLUSIONS

- Indigenous bacteria successful at degradation of 1,4-dioxane and THF
- System capable of treating 6 gpm of 25,000 μg/L 1,4-dioxane to less than 1 μg/L (>99.9% removal efficiency)
- System capable of treating 6 gpm of 60,000 μg/L THF to less than 1 μg/L (>99.9% removal efficiency)
- Organic loading (F/M ratio) between 0.04 and 0.07 g D&T COD/g TS*d resulted in high removal efficiencies
- Nitrification is occurring with no inhibitory effect on 1,4-dioxane degradation
- Temperature control (at approximately 23^{o}C) is necessary to maintain high removal efficiencies
- No longer need UV Oxidation system because of robustness of biological system
- Other VOCs in process waters are treated in the biological system

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- Dr. Leslie Grady – Clemson University
- Dr. Craig Adams – U. of Missouri

QUESTIONS?

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