PARSONS

EMSI

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

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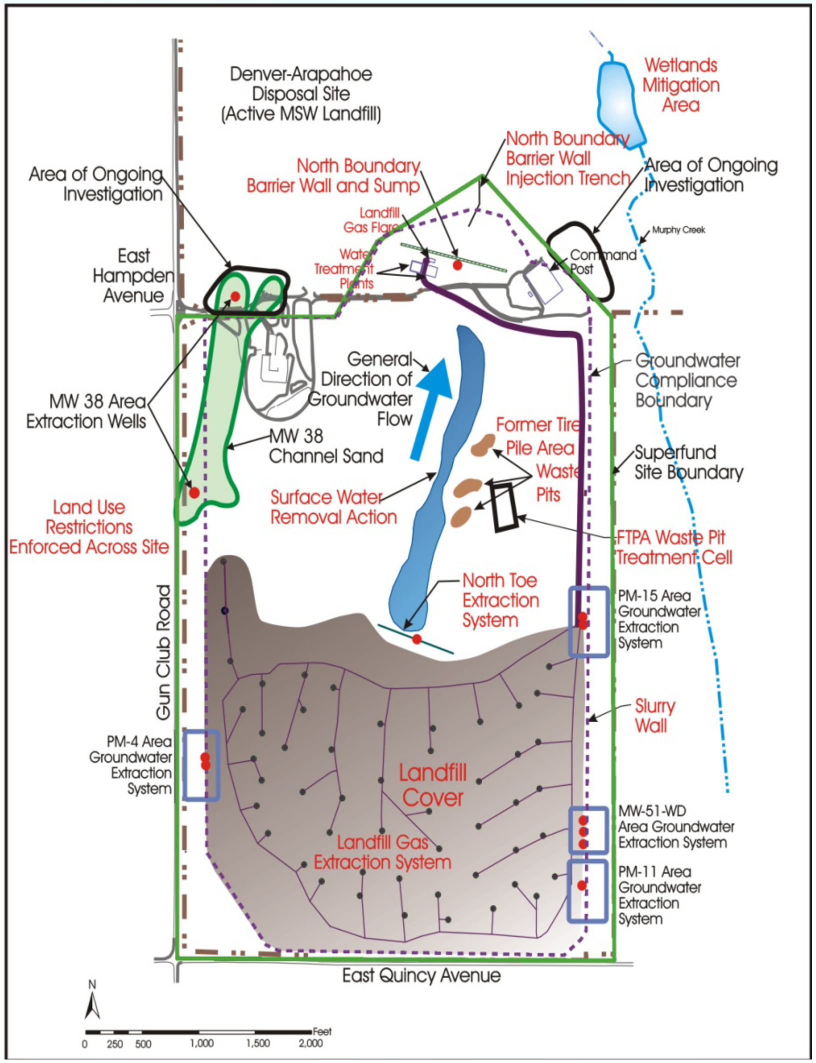
(presented at Federal Remediation Technologies Roundtable, 2006 and Battelle - Monterey, 2008)

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



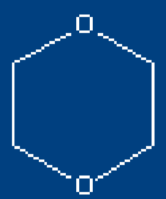
OPERATIONS

- 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

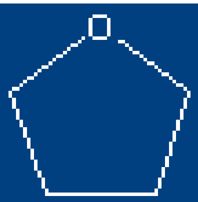
- Treatment train cannot remove 1,4-dioxane to below permit (2.0 ppm) due to poor UV transmittance, hydroxyl scavenging with NTES waters, and poor sorption on GAC
- Other permit parameters can be met by GAC alone
- Evaluated a number of technologies:
  - Chemical precipitation (to remove UV-Oxidation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

LITERATURE SEARCH



1,4-dioxane

$C_4H_8O_2$



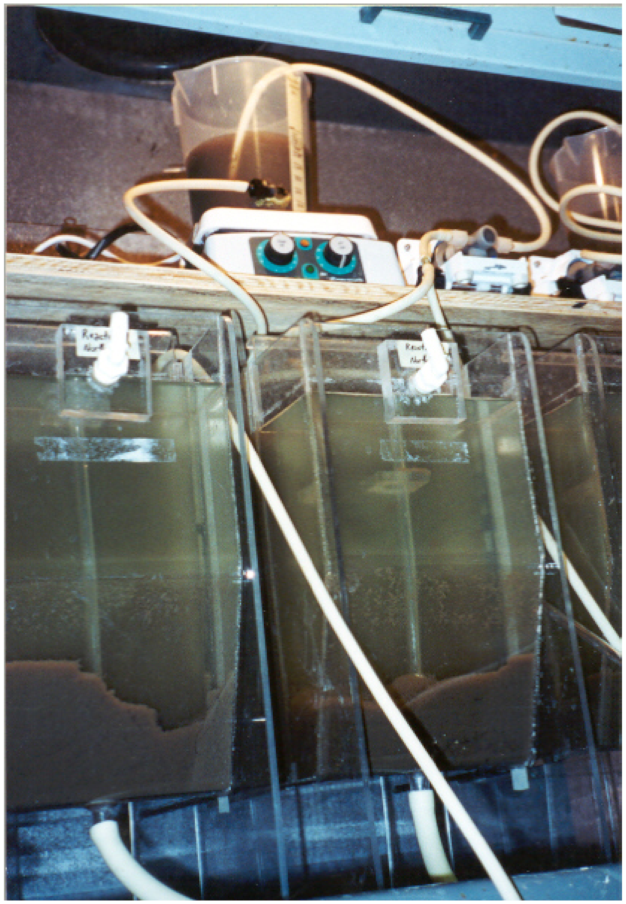
THF

C_4H_8O

- Clemson University
  - Reactors operated at $35^{o}C$
  - Attached growth bio-reactor
  - 1,4-dioxane removal as sole substrate
  - Reaction efficiency decreased sharply with temperature
- NC State
  - Reactors operated at $35^{o}C$
  - 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 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

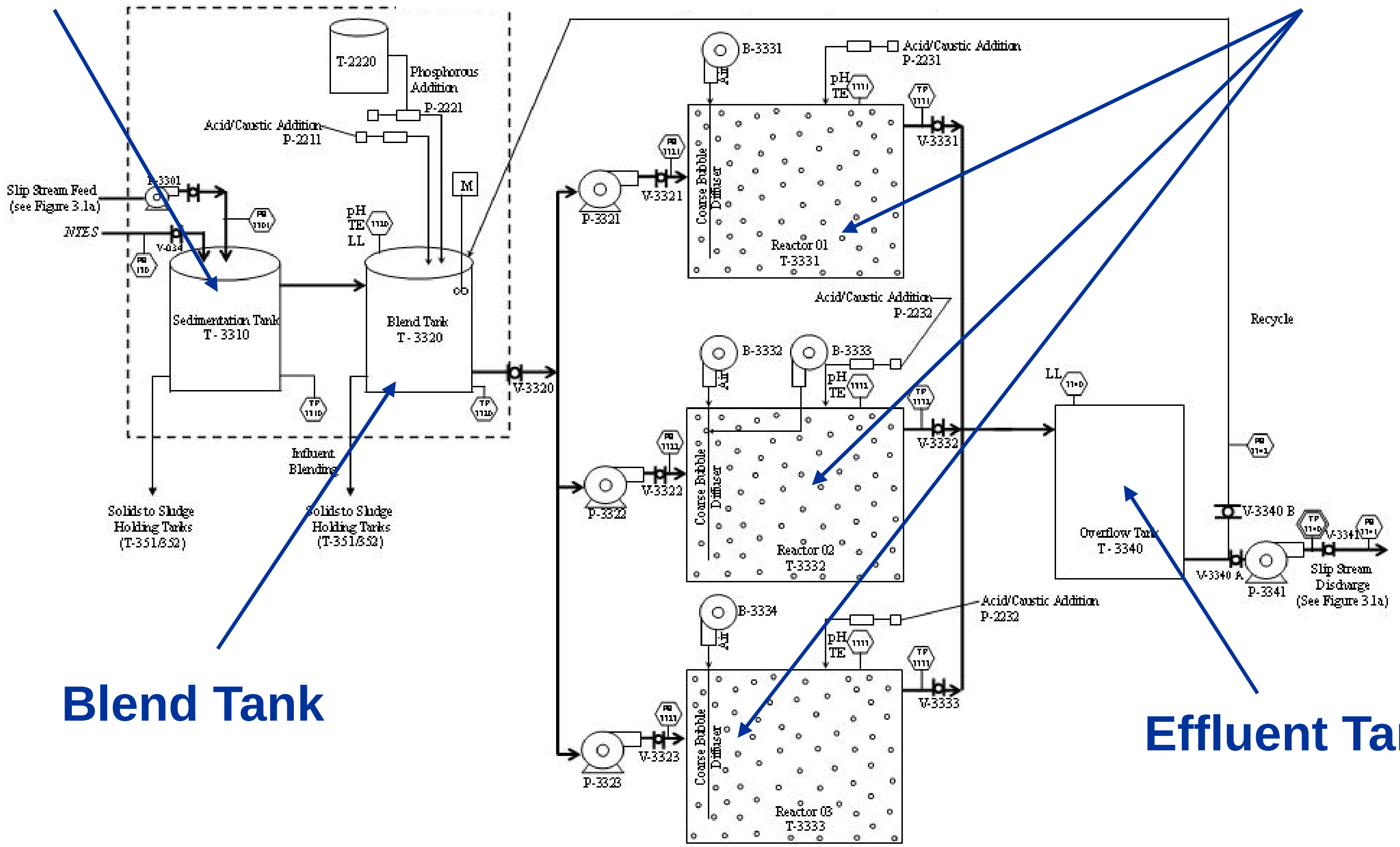
DESIGN AND OPERATION

- 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)

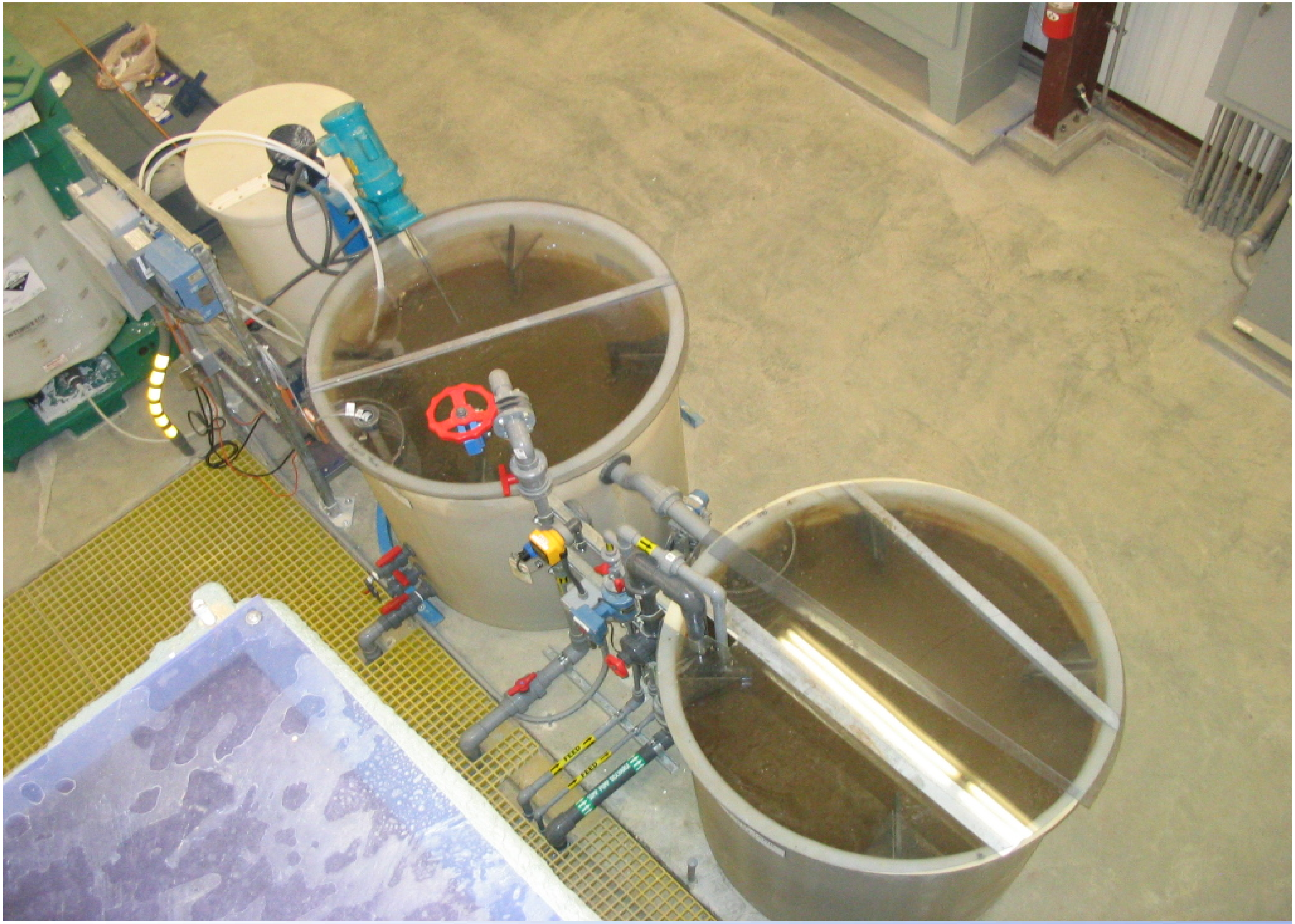
Sedimentation Tank

3 MBBRs



Blend Tank

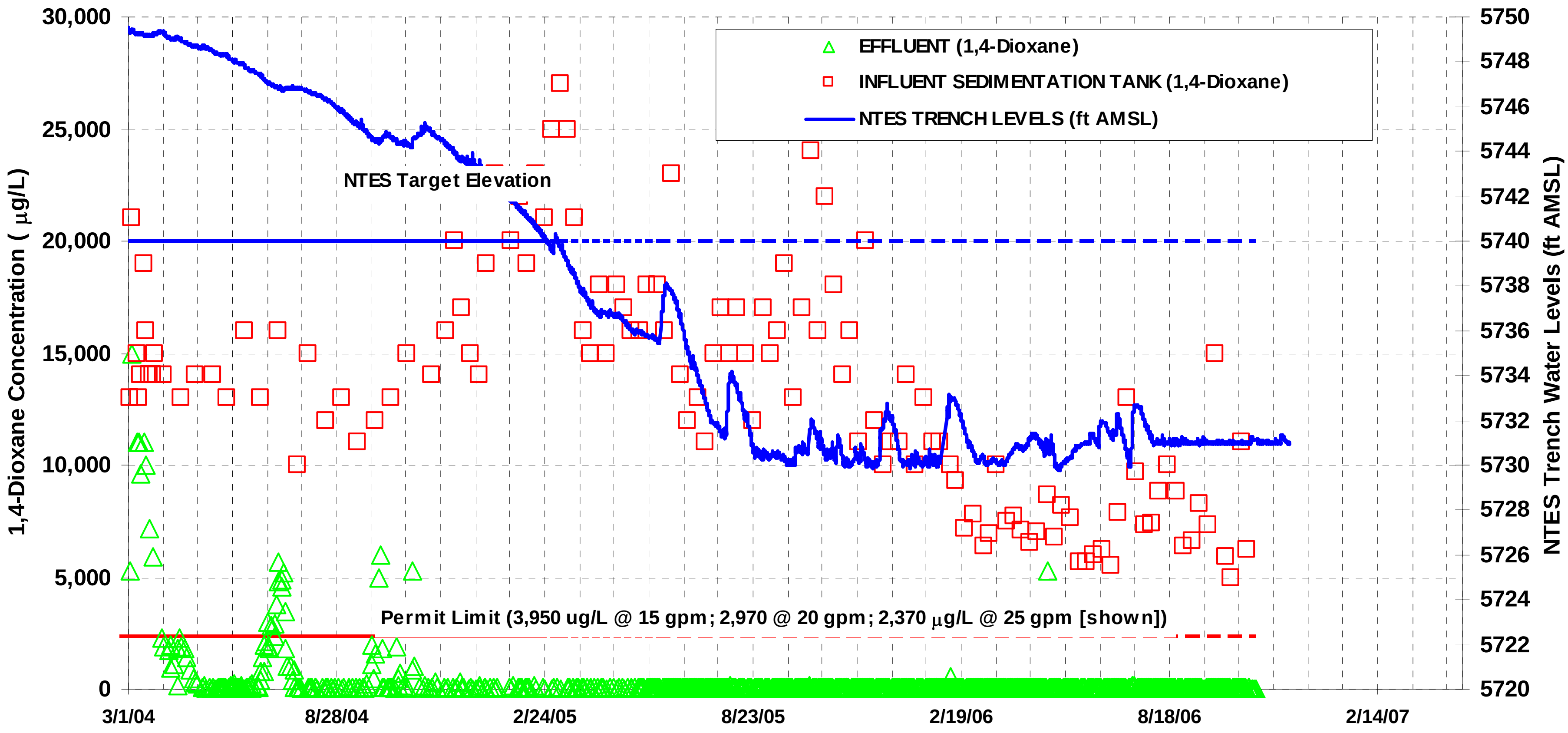
Effluent Tank



RESULTS

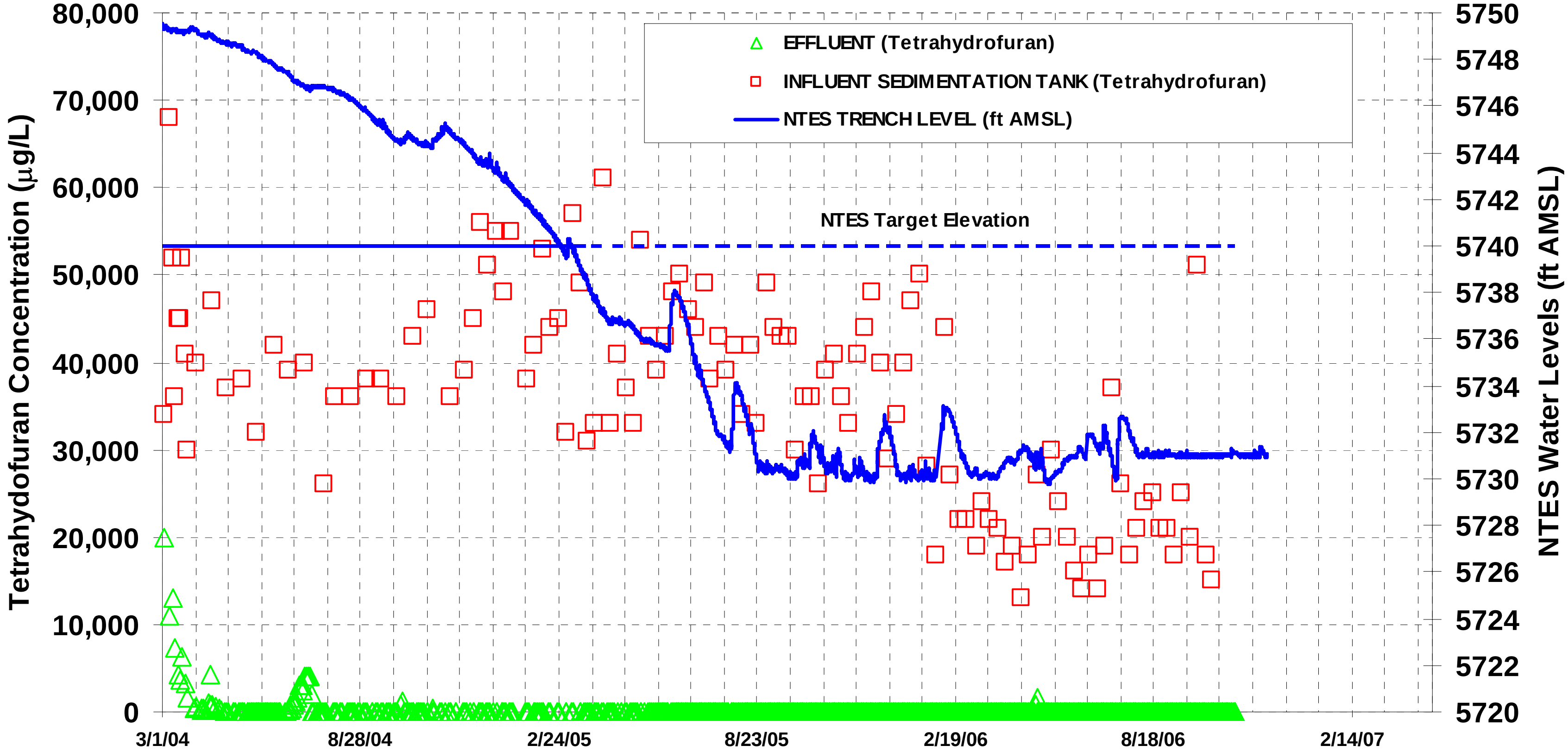
- Acclimation began in March 2004
  - Seeded with indigenous bacteria inherent to the raw NTES stream
  - Low flow-rate (1.3 gpm)
- Transition began in May 2004
  - Flowrates between 2.7 and 6.0 gpm
- Full-Scale operations began in January 2005
  - Maximum flowrate of 6.0 gpm
  - Successful compliance testing

1,4-DIOXANE

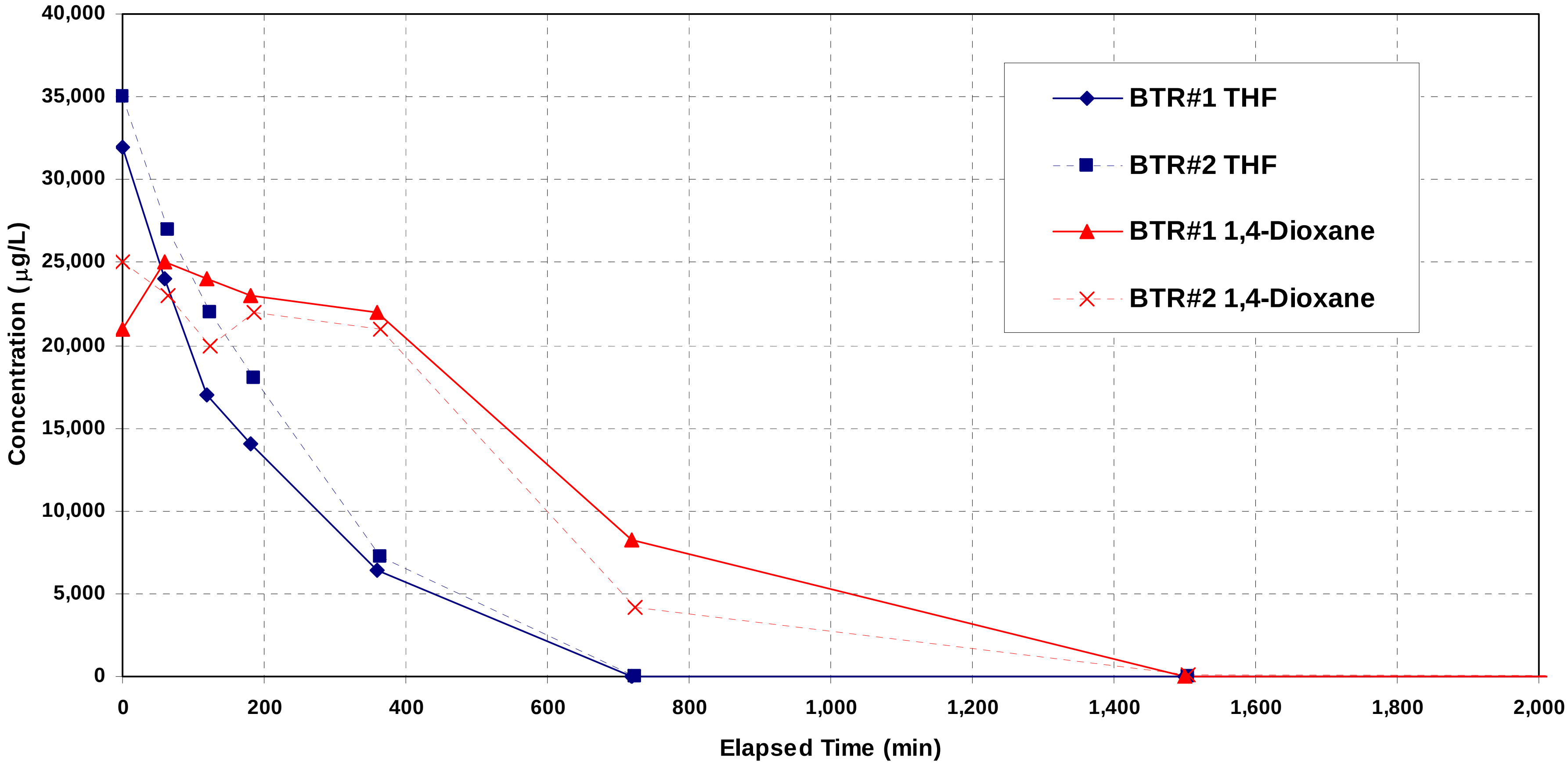


EFFLUENT (1,4-Dioxane)
INFLUENT SEDIMENTATION TANK (1,4-Dioxane)
NTES TRENCH LEVELS (ft AMSL)
NTES Target Elevation
Permit Limit (3,950 ug/L @ 15 gpm; 2,970 @ 20 gpm; 2,370 μg/L @ 25 gpm [shown])
1,4-Dioxane Concentration (μg/L)
NTES Trench Water Levels (ft AMSL)
30,000
25,000
20,000
15,000
10,000
5,000
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

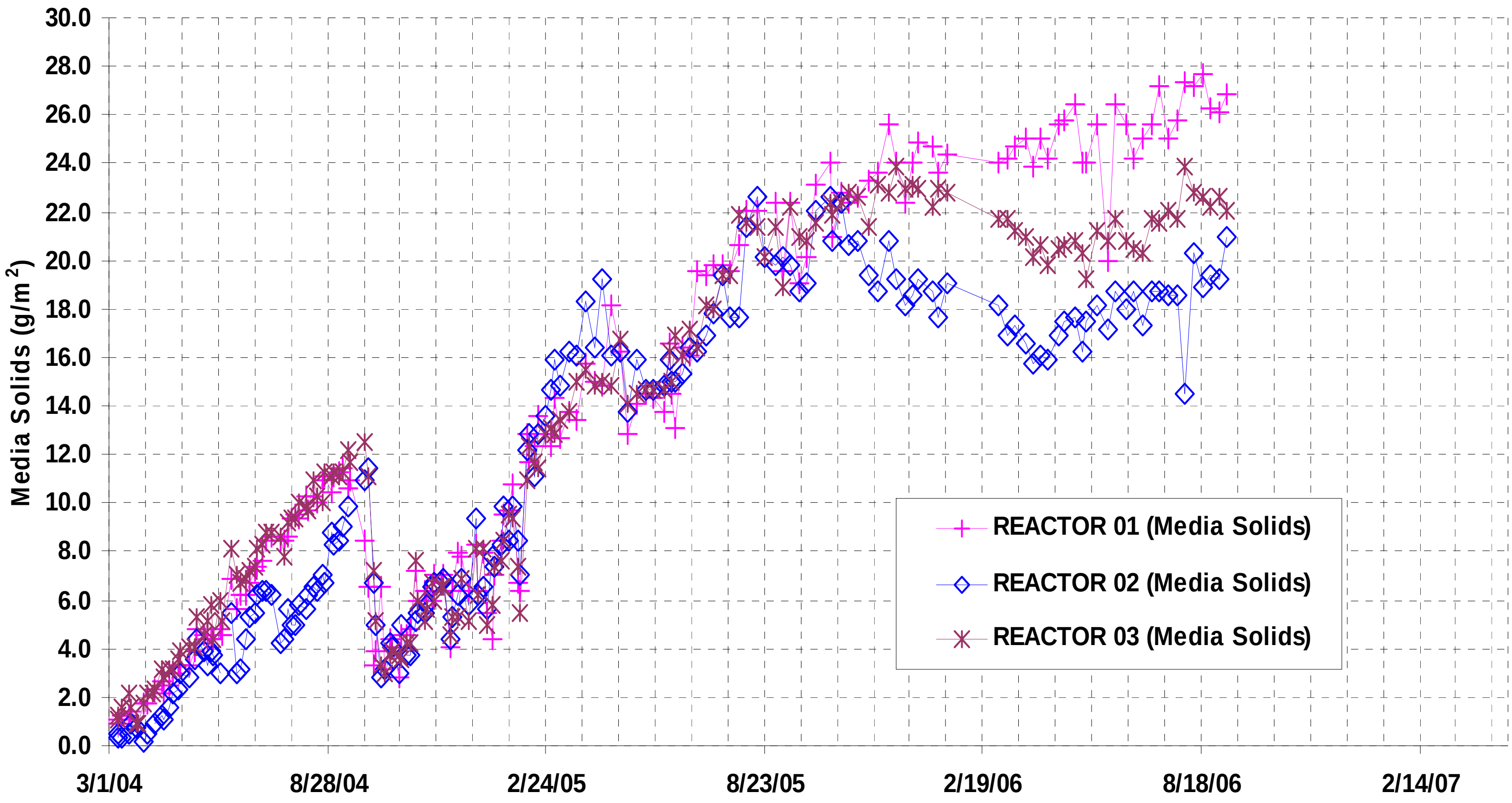
TETRAHYDROFURAN



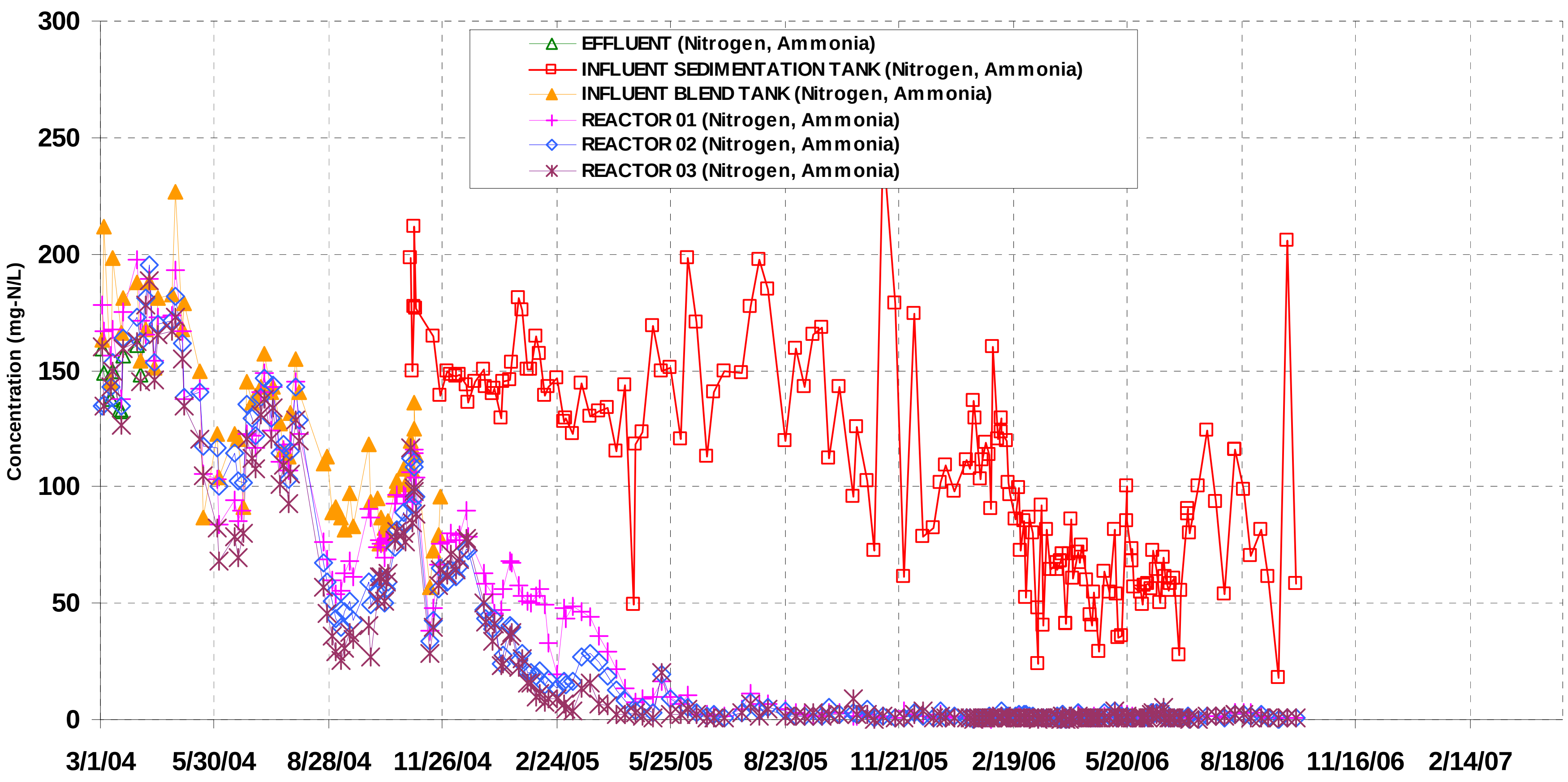
EXAMPLE DEGRADATION PROFILE



MEDIA SOLIDS



AMMONIA



300
250
200
150
100
50
0
Concentration (mg-N/L)
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)
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

2007-2009 BioSystem Changes

- 2007: Increased Contaminant Loading by 2 gpm
  - Added groundwater containing 1,4-dioxane and 1,2-DCA
  - Added landfill gas condensate containing 1,4-dioxane, THF, CVOCs, and BTEX
- 2009: Increased Blend Water Flow by 2.5 gpm
  - NBBW groundwater containing 1,500 ug/L 1,4-dioxane
- Net flow to reactors = 10.5 gpm
- Total flow with recycle = 15 gpm
- Dioxane and THF effluent concentrations < detection limits

CONCLUSIONS

- Indigenous bacteria successful at degradation of 1,4-dioxane and THF
- System currently treating 10.5 gpm of 5,000-10,000 ug/L 1,4-dioxane to less than 50 μg/L (>99% removal efficiency)
- System currently treating 10.5 gpm of 20,000 μg/L THF to less than 13 μg/L (>99% 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 (23^{o}C) and pH (7) controls essential to maintain high removal efficiencies
- UV Oxidation system off line; GAC use minimized
- Effective biodegradation of CVOCs and BTEX occurring
- Self-regulating with minimal operator intervention

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- Dr. Craig Adams – U. of Missouri

QUESTIONS?

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