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Revised Field Evaluation of Biodegradation at the French Limited Site (Phase II) Volume I

(With Ammendment section describing the EPA and TWC comments and the French Limited Task Group response to those comments.)

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BIODEGRADATION FIELD TEST - PHASE II REPORT
FRENCH LIMITED SITE

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1.0 EXECUTIVE SUMMARY

The French Limited Task Group has initiated a program to develop a technical data and practical experience base, for using biotreatment technology to remediate the French Limited Site wastes. Laboratory tests have confirmed that the technology is applicable. (See Resource Engineering Report - Laboratory Evaluation of Biodegradation at the French Limited Site - December, 1986). Based on the results of the laboratory evaluation a large scale Field Test Program was conducted from December 26, 1986 to February 13, 1987. The Field Test Program was designed to scale-up the laboratory tests to field conditions by utilizing two large tanks for biodegradation of sludges from two separate locations in the lagoon. As in the laboratory evaluation, the lagoon water and the sludge itself provided the source of indigenous micro-organisms. Approximately 9,000 gallons of lagoon water was placed in each tank. 790 gallons of sludge from the east end of the lagoon was added to Vessel 1, and 580 gallons of sludge from the west end of the lagoon was added to Vessel 2.

Agitation of the mixture was accomplished by circulation pumping at approximately 500 gpm flow rate, combined with periodic air lance agitation. The air lancing was necessary to lift settled sludges from the tank bottoms.

The pH in each tank was adjusted, and maintained between 7.0 and 8.0, and appropriate nutrients added to stimulate the biodegradation process. The test was operated for 49 days after initial loading of the sludges.

Weekly samples of the sludge were obtained for priority pollutant (GC/MS) analysis, with sludge sample splits being provided to a laboratory selected by the EPA for duplicate analysis.

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Biweekly air emissions samples (4 to 8 hour composite) were collected from the vessel head space for a priority pollutant analysis, to assess the compounds released from the biodegradation operation.

The field biodegradation evaluation has confirmed the laboratory conclusions; ie: that the French Limited sludges are biodegradable utilizing a liquid/liquid matrix of lagoon water and sludge.

Review of the analytical data reveals that a ten fold reduction of volatiles and base neutrals was achieved in Vessel 2, and a ten fold reduction of volatiles was achieved in Vessel 1. The test experienced an interruption in the growth of the micro-organism population due to an unanticipated increase in oxygen demand when degradation of the more "difficult" high molecular weight compounds began. This occurred after an initial period when the lower molecular weight materials were being degraded. This interruption, combined with a delay in achieving a homogenuous sludge/water mix during the first 2 weeks of the test resulted in the sludge biodegradation being incomplete at the end of the 49 day test.

Data describing the degree of sludge degradation achieved during the test is shown in Section 6.0 of this report. This information will provide the data base on which to base the next phase of biodegradation development.

The laboratory evaluation of biodegradation combined with the results from this field test indicate that proceeding to the next step in the development of the French Limited biodegradation process is justified. The next development step should be directed at demonstrating the mechanics of how bioremediation of the lagoon would be accomplished, and defining the economics of the biodegradation remedial alternatives.

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2.0 INTRODUCTION

In the course of planning for the French Limited Site Feasibility Study, it was believed that biological treatment of the waste was a viable remedial alternative. Based on this belief, the French Limited Task Group initiated a program to develop a technical data and practical experience base for using biotreatment technology on the French Limited waste sludges, contaminated water, and contaminated soil. Laboratory tests confirmed that the technology is applicable. (See Resource Engineering Report - Laboratory Evaluation of Biodegradation at the French Limited Site, December, 1986 shown in Appendix 1). The test results verified excellent biodegradation of the waste constituents, and based on those results, a large scale field tank test program was conducted from December 26, 1986 to February 13, 1987.

The program approach for the field tank test program consisted of the following methodology steps:

- The lagoon water and the sludge itself provided the source of indigenous micro-organisms.

- The sludge/water mixture was to be biotreated in tanks located on the lagoon shore.

- Agitation of the mixture was maintained by circulation pumping of the sludge/water mixture, combined with periodic air agitation.

- Weekly samples of the sludge were obtained for a priority pollutant GC/MS analysis. Sludge sample splits were provided to a laboratory selected by the EPA for duplicate analysis.

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- Biweekly samples of air emissions were taken from the vessel head space for a priority pollutant analysis.

A description of the equipment and procedures used in the field test tank program together with the results and conclusions from the program is presented in this report.

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3.0 EQUIPMENT DESCRIPTION

A schematic flow diagram depicting the equipment described in Sections 3.1, 3.2, 3.3, 3.4, and 3.5 is shown on Figure 3-1. All the equipment for this test was installed in a filled, graded area near the lagoon which provided for spill and stormwater runoff control. The location of this test area is also shown on Figure 3-1.

3.1 Biodegradation Vessels

The biodegradation vessels used in the field test were two 500-barrel capacity portable vessels (Frac Tanks) which were formerly used in oil field service. The tanks were cleaned prior to being used in the field test. Overall dimensions of the vessels were approximately 35' L x 8' W x 12' H.

Each vessel was equipped with two internal plate type heat exchangers having a surface area of approximately 128 square feet. Heated water was circulated through these plates to aid in controlling the temperature of the sludge/water mixture in the biodegradation vessels.

Two 4' L x 8' W sections from the top of each vessel were removed during the field test for sludge loading, observation, sampling, and sludge mixing during the test. Access to the top of each tank was provided by a ladder, while scaffolding was installed on top of and between the tanks to provide a working platform. It was initially thought that it would be necessary to insulate the vessels to maintain a temperature suitable for biodegradation, but operating experience indicated that insulation was not required.

The north end (as installed) of each vessel was equipped with two 4-inch flanged connections (sludge/water circulation), two 2-inch screwed connections (hot water circulation), and a

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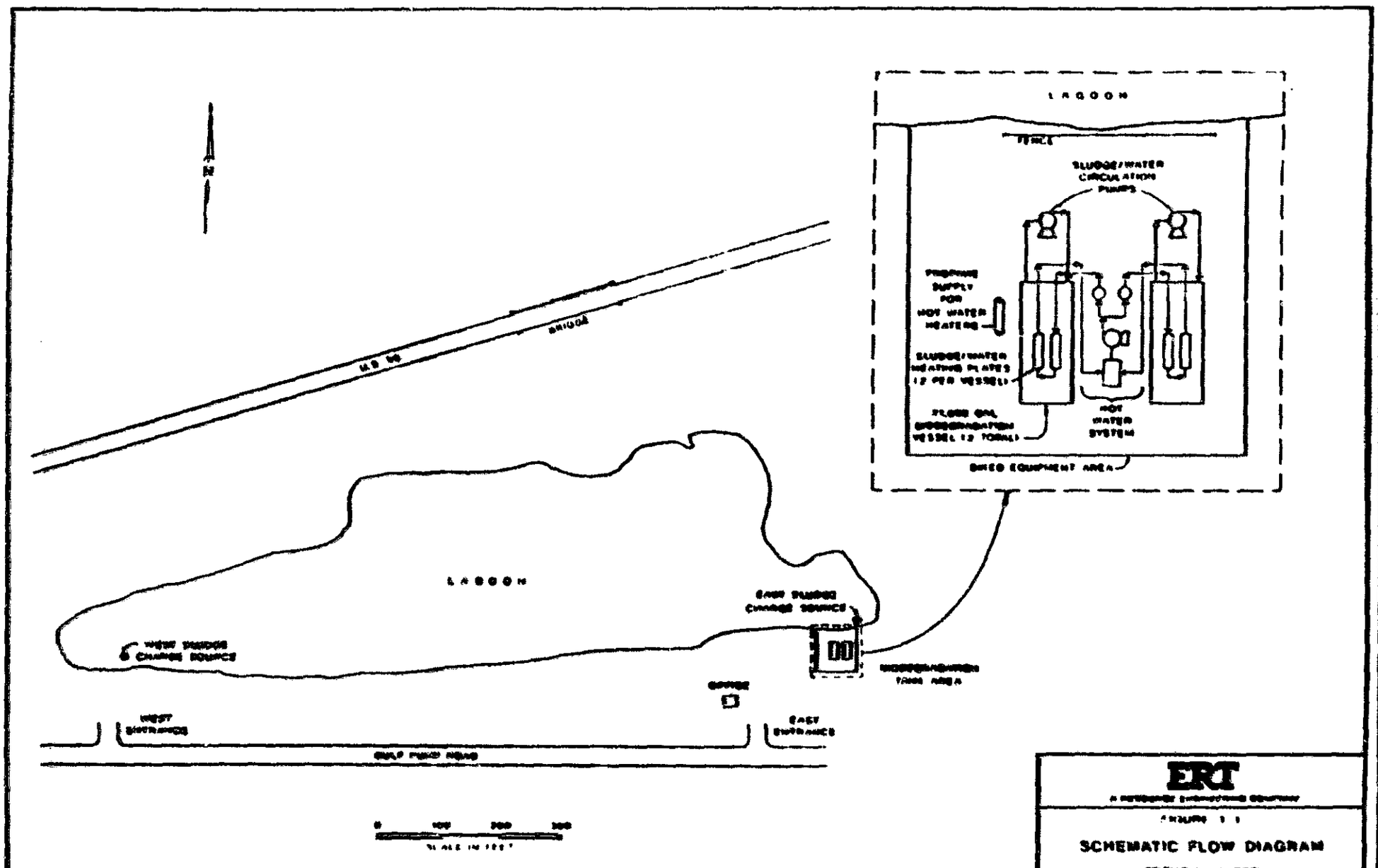

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SCHEMATIC FLOW DIAGRAM

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3-inch flanged connection which was used for temperature measurement of the sludge/water mixture in the biodegradation vessels.

3.2 Sludge/Water Circulating Pumps

The pumps used in this service were diesel-powered "trash pumps" with 4-inch suction and discharge connections. The circulation rate of the sludge/water mixture was approximately 500 gallons/minute. Connections were provided so that the pumps could be used to fill the biodegradation vessels with lagoon water prior to sludge loading.

In addition, a 1-1/2-inch connection was provided on each pump discharge to divert part of the circulation to the top of the tanks. This connection was used to provide water to wash sludge out of the trackhoe bucket during the sludge loading operation, and for the water lancing which is described in Section 4.2.

3.3 Hot Water Circulating System

The hot water circulating system consisted of a 120-gallon reservoir, a circulating pump, and two 40,000 BTU/HR LPG-fired hot water heaters. The flow from the hot water circulating pump was split at the pump discharge, and sent through the two water heaters (each biodegradation vessel having its own heater), to the internal heat exchanger plates in the biodegradation vessels and back to the reservoir on the suction side of the hot water circulating pump.

Operating experience indicated the LPg-Fired water heaters were only required during periods of sub-freezing temperatures.

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The work (i.e., horsepower) transfered to the circulating sludge/water mixture from the diesel driven circulating pumps was equivalent to 30,000-40,000 BTU/HR and this heat input was sufficient to maintain a 60°F minimum water temperature except in the coldest weather.

3.4 Air Lancing System

The air lancing system was installed to provide a means of disturbing the sludge layer on the bottom of the biodegradation vessels. This procedure was developed after it was determined that the combination of pump circulation and water lancing was not adequate to disperse the sludge into the water. The air lances consisted of 3/4-inch pipes long enough to reach the bottom of the vessels. A portable air compressor having a 125 psig discharge pressure and a 100 cubic feet/minute capacity provided air to the lance.

3.5 Air Sparging System

The air sparging system was installed on day 33 of the 49 day test after it was noted that oxygen consumption of the biodegradation process was greater than that which could be provided by the combination of air lancing, and air contact with the circulating sludge/water mixture. The air sparging system was constructed of 1-inch PVC pipe drilled with a number of 1/16 inch holes. The perforated pipe was installed approximately one foot above the bottom of the biodegradation vessels. The same compressor used for air lancing was also used for air sparging. The air sparging system was successful in maintaining at least 2 mg/l dissolved oxygen in the circulating sludge/water mixture through the remainder of the test.

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4.0 PROCEDURES

A field log of the activities involved in the biodegradation field test was maintained throughout the 49 day period. A separate logsheet was used for each tank. These "French Biodegradation Time Charts" present the tank operations data that was regularly logged, as well as notes on special operating steps performed. The time charts are shown in Appendix 1.

4.1 Sludge Loading Procedure

Approximately 9,000 gallons of lagoon water was pumped into each of the vessels and continuously circulated during the sludge loading process.

Sludge loading was planned to be carried out in two steps with three days of equilibration between each step. Sludge was scooped out of the east and west ends of the lagoon at the locations shown on Figure 3-1 using a trackhoe with a 5/8 cubic yard bucket. The sludge was washed out of the bucket into the designated biodegradation vessel using the water lance supplied by the circulating pump discharge as described in Section 3.2. Sludge from the east end of the lagoon was placed in the east vessel (Tank #1) and sludge from the west end went to the west vessel (Tank #2).

The Microtox Toxicity Analysis of the sludge/water mixture after the first step of sludge loading indicated higher than expected results in Tank #2 so the second loading event for this tank was cancelled. The pH of the circulating mixture in each vessel was adjusted to between 7.0 - 8.0 after sludge loading. Dolomitic limestone was added to the circulating sludge/water mixture in the east biodegradation vessel (Tank #1), whose pH was approximately 5.0 after sludge loading.

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Phosphoric acid was added to the circulating mixture in the west tank, whose pH was approximately 11.0 after sludge loading. The nutrient requirements of the mixture in each vessel were calculated after compensating for the materials used in pH adjustment, and were added after the pH of each vessel was between 7.0 - 8.0. The approximate quantities of sludge, lagoon water, pH adjustment chemicals, and nutrients loaded into each vessel are shown in Appendix 1.

4.2 Operating Procedure

As implied in Section 3.0 (Equipment Description), the operating procedure for the field test was adjusted as equipment was added to respond to changes in operating requirements. The evolution in operating equipment can be traced in the notes shown in Appendix 1, but are generally described in the following steps:

1. Sludge/water movement by circulation pumping only.

2. Use of 1-1/2 inch diameter hoses from circulating pump discharge to provide water for agitation of the sludge layer on the bottom of the biodegradation vessels (water lancing). These 1-1/2 inch hoses were attached to the same 3/4-inch pipes that are described in Section 3.4.

3. Use of an air compressor with the same 1-1/2 inch diameter hoses and 3/4-inch inch pipes noted in (2) above for sludge layer agitation (air lancing). This technique replaced water lancing as a means of agitating the sludge.

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4. Use of PVC air spargers to maintain a dissolved oxygen level suitable for biodegradation.

The normal operating and safety procedures for the biodegradation field test after air sparger installation are described below.

- The sludge/water circulating pumps were operated on a 24 hour/day basis with the following exceptions:
  - The circulating pumps were shut down Thursday evening to allow sampling of the settled sludge layer in the biodegradation vessels on Friday morning prior to air lancing. They were re-started Friday morning after obtaining the sludge sample.
  - The circulating pumps were shutdown approximately one hour/week for routine maintenance of the diesel engine.

- Air lancing was carried out twice/week on Tuesday and Friday. Moving the air lances around the bottom of the biodegradation vessels required approximately 1-2 hours to ensure thorough sludge agitation. Personnel carrying out this operation wore protective coveralls, gloves, boots, hearing protection, and cartridge respirators during this operation.

- Air sparging was performed as required to maintain 2 mg/l dissolved oxygen in the circualting sludge/water mixture. Personnel on top of the biodegradation vessels during air sparging wore protective gloves, boots, hearing protection, and cartridge respirators.

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- Temperature measurement of the sludge/water mixture in the biodegradation vessels and the hot water system was recorded hourly.

- Hearing protection was required for routine data logging, maintenance, and sampling because of the high noise level associated with the diesel-powered circulating pumps and air compressor.

4.3 Sampling Procedure

The sampling and analytical schedule that was followed during the biodegradation field test is shown in Table 4-1. It differs from that presented in Section 4.0 (Sampling Frequency and Analysis) of the ERT report Proposed Field Evaluation of Biodegradation at the French Limited Site (December 1986) in the following respects:

- Beginning on January 16 (Day 21), Microtox analyses and plate counts were taken three times/week from each biodegradation vessel to monitor biodegradation activity instead of once/week as originally proposed.

- HNU readings were taken on a daily basis after January 16 to provide data on air emissions.

- Air sampling using polyurethane foam (PUF) and charcoal tube detectors was carried out after the initial sludge load and regularly after air lancing beginning January 12 (Day 17). Meteorological conditions of persistent fog and rain prevented air sampling prior to Day 17.

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TABLE 4-1

FRENCH LIMITED BIODEGRADATION BATTELLE AND ANALYTICAL SCHEDULE

Task	Operating Day	Field Temp.	Field pH	Field D.O.	Field Biomass	Phoenix Microtox	BRT Flow Ct.	BRT Soluble BOD	BRT Soluble COD	BRT Soluble TSS	BRT Soluble OGC	BRT Soluble NITRO	BRT Soluble NO_3	BRT Soluble NO_2	BRT Soluble S	BRT Soluble SO_4	BRT Soluble Cl^-	BRT Soluble Ca	BRT Soluble Metals	BRT Soluble TOC	SPE/Tox A/B Volatiles	SPE/Tox A/B Pesticides	SPE/Tox A/B PAH's	
Charge reactor, equilibration	-6	6	6																		2	2	2	Composite sample of each sludge
	-5	6	6																					
	-4	6	6			2	2																	
Loading adjustment, equilibration	-2	6	6																					
	-1	6	6																					
	0	6	6		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	1	Daily for duration of study			2																			
	2				2																			
	3				2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2			
	4				2																			
	5				2																			
	6				2																			
	7				2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
	14				2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2/2	2/2	2/2	
	21				2	6/wk	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2/2	2/2	2/2	
	28				10/wk		10/wk	2	2	2	2	2	2	2	2	2	2	2	2	2	2/2	2/2	2/2	
	35			Frequently as needed				2	2	2	2	2	2	2	2	2	2	2	2	2	2/2	2/2	2/2	
	42							2	2	2	2	2	2	2	2	2	2	2	2	2	2/2	2/2	2/2	
	49							2	2	2	2	2	2	2	2	2	2	2	2	2	2/2	2/2	2/2	

Notes: 2/2 means two sludge samples before agitation from each vessel. two second routine samples after agitation from each vessel

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- Separate sludge and sludge/water mixed liquor samples were taken before and after air lancing beginning January 9 (Day 14) for full priority pollutant GC/MS analysis.

- Dissolved oxygen (D.O.) was not measured until January 27 (Day 32) because the oil and grease content of the circulating sludge/water mixture tended to foul the membrane of the D.O. meter. A wet chemical technique to determine D.O. content based on a color change when titrating the mixture was also unsuccessful. The circulating mixture in the biodegradation vessels was clear enough after Day 32 to use the D.O. meter, and frequent analyses were made after that point.

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All samples were collected in appropriate clean containers, preserved as required, and submitted to the laboratory for analysis in accordance with French Limited site sampling and analytical procedures (RI Report, June 1986).

HNU and pH readings, sludge/water daily average temperatures, and operational comments are found in Appendix 1.

4.4 Vessel Unloading Procedure

The biodegradation vessels were unloaded in two steps:

1. The water was drained back to the lagoon through a filter to assure all solids were retained.

2. The solids were collected from the filter and the tank bottom and placed in 55-gallon drums.

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Personnel carrying out this operation wore supplied air respirators, hard hats with face shields, protective coveralls, gloves, and boots. Standard industrial vessel entry procedures were followed during this operation.

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5.0 ANALYTICAL METHODS

5.1 Biological Evaluations

The relative toxicity of the sludge/water mixed liquor was measured at regular intervals with the Microtox™ bioassay. The bioassay provides a measure of relative toxicity based on a reduction in bioluminescence of the Luciferase enzyme system of the marine bacterium Photobacterium phosphoreum. Details of extraction procedures, sample preparation, and test parameters appear in the Resource Engineering Report Laboratory Evaluation of Biodegradation at the French Limited Site, December 1986. A copy of this report is provided in Appendix 2.

Since loading capacities much higher than the sludge EC_{50} value (see Appendix 2 - Laboratory Evaluation Report, Section 4.3, for definition of EC_{50}) were used in this biodegradation study, relative toxicity measurements were standardized to the $\%EC_{50}$ value of each sample. Four dilutions of each sample (50%, 25%, 12.5%, 6.25%) were evaluated by Microtox and the $\%EC_{50}$ value was determined by plotting the gamma values against concentration. In addition to identifying the $\%EC_{50}$, this plot indicated qualitative and quantitative toxicity differences in succeeding samples.

Microorganism populations were enumerated according to standard microbiological methods (EPA Microbiological Manual 1978) on Nutrient Agar. The highest enumeration efficiency was obtained with Nutrient Agar in a preliminary comparison with Trypticase Soy Agar and Brain-Heart Infusion Agar. Colony Forming Units (CFU) were counted 4 days after incubation at room temperature.

Biomass activity, based on the catalase enzyme system, was measured with the HMB System (Biotech International Inc., Bellaire, Texas) according to the manufacturer's

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recommendations. The assay measures gas production of viable aerobic and facultative anaerobic organisms after exposure to hydrogen peroxide.

5.2 Waste Water Treatment Parameters

BOD_5 was determined with an acclimated municipal sludge according to Standard Method #507. Other parameters were analyzed according to Standard Methods, 16th Edition, as follows:

Total Suspended Solids (TSS)	209C
Total Kjeldahl Nitrogen (TKN)	420A
Dissolved Oxygen (D.O.) (membrane electrode, YSI meter)	421F
Oil and Grease	503A
Total Organic Carbon (TOC)	505A
Chemical Oxygen Demand (COD)	508A

5.3 Priority Pollutant Organics

Sludge and water samples were analyzed according to standard EPA analytical methods #SW 846 and #600 respectively as specified:

	Method	
	Water	Sludge
Volatiles	624	8240
Base/Neutral Extractables	625	8250
Acid Extractables	625	8250
Pesticides	625	8250
PCBs	608	8250

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5.4 Inorganics

Analytical methods in Standard Methods, 16th Edition, were used as follows: #303A for copper, potassium, chromium, lead, cadmium, and silver; #303C for barium; #303E for arsenic and selenium; #303F for mercury; #407A,B for chloride; #418A for nitrate; #424C,D for phosphate; and #426C for sulfate.

5.5 Air Emissions

Volatile and semi-volatile organic emissions were collected from the headspace of each bioreactor by adsorption on charcoal tubes and polyurethane foam (PUF), respectively. Air sample volume and duration were regulated by an Alpha 1 programmable pump adjusted for collection periods of at least 4 hours but not more than 8 hours. For volatiles, quantitative analysis for benzene, toluene, ethyl benzene, and the four compounds present in the highest concentration was reported. The total spectrum of volatiles evaluated in this scan is shown in Table 5-1. For semi-volatiles, the standard 16 compound PNA scan was conducted.

5.6 Laboratory Reports

The Detailed Laboratory Reports for the various analyses described in this report are shown in Appendix 3.

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TABLE 5-1

SUMMARY OF THE VOLATILE PRIORITY POLLUTANTS AND APPENDIX IX COMPOUNDS SCANNED FOR IN THE HEADSPACE AIR SAMPLE ANALYSES

Chloromethane
Bromoethane
Vinyl Chloride
Chloroethane
Methylene Chloride
Acetone
Carbon Disulfide
1,1-Dichloroethene
1,1-Dichloroethane
Trans-1,2-Dichloroethene
Chloroform
1,2-Dichloroethane
2-Butanone
1,1,1-Trichloroethane
Carbon Tetrachloride
Vinyl Acetate
Bromodichloromethane
1,2-Dichloropropane
Trans-1,3-Dichloropropene
Trichloroethene
Dibromochloromethane
1,1,2-Trichloroethane
Benzene
Cis-1,3-Dichloropropene
2-Chloroethylvinylether
Bromoform
2-Hexanone
4-Methyl-2-Pentanone
Tetrachloroethene
1,1,2,2-Tetrachloroethane
Toluene
Chlorobenzene
Ethylbenzene
Styrene
Total Xylenes
Dichlorodifluoromethane
1,2-Dibromo-3-Chloropropane
Trichlorofluoromethane
Acetonitrile
Acrylonitrile
Iodomethane
Ethyl Cyanide
Allyl Chloride
Allyl Alcohol
Dibromoethane
Methacrylonitrile
1,4-Dioxane
2-Chloro-1,3-Butadiene
1,2-Dibromoethane
Methyl Methacrylate
1,1,1,2-Tetrachloroethane
1,2,3-Trichloropropane
1,4-Dichloro-2-Butene
Ethyl Methacrylate
Acrolein

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6.0 ANALYTICAL RESULTS

6.1 Biological Evaluation from Vessel 1

Gamma values (see Appendix 2 - Laboratory Evaluation Report, Section 4.3, for definition of Gamma Values) and the respective $\%EC_{50}$ values for the mixed liquor and sludge of Vessel 1 are summarized in Table 6-1 and are also shown in graph form on Figure 6-1. Percent EC_{50} values increase as the relative toxicity of the sample decreases. The highest toxicities were recorded on Day 0 and Day 7. The lowest toxicity, recorded on Day -1, reflects inadequate mixing and equilibration following sludge loading. The relative toxicity of sludge decreased from Day 21 to Day 52.

Microbiological counts, relative catalase activity, and dissolved oxygen values during biodegradation in Vessel 1 are summarized in Table 6-2 and are also shown in graph form on Figure 6-2. The biomass generally increased in both numbers of colony forming units and in biological activity, as expressed by catalase activity, when dissolved oxygen increased during the last 15 days. Catalase activity is consistently and significantly higher after air lancing in all cases. This can be attributed to induction or activation of the catalase system in response to vigorous air injection during a short period. Pre-lancing levels are low because the 12-hour quiescent period, prior to sampling and air lancing, suppresses catalase activity or favors enzyme turnover related to oxygen limiting conditions. Conversely, the number of colony forming units increases during the quiescent period then decreases during air lancing and mixing. Since many microorganisms attach to suspended organic matter during vigorous mixing, flocculation may remove or consolidate some colony forming units in this assay.

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TABLE 6-1

MICROTOX™ GAMMA VALUES AND
% EC_{50} FOR MIXED LIQUOR
AND SLUDGE FROM VESSEL 1 DURING BIODEGRADATION

		Dilution				
	Day	50%	25%	12.5%	6.25%	%EC_{50}
Mixed Liquor	-3	70.12	18.32	4.50	1.57	4.60
	-1	2.43	1.25	0.69	0.37	11.00
	0	20.21	14.03	9.00	6.11	0.25
	3	9.73	7.58	3.96	2.72	1.35
	7	19.66	15.88	9.11	6.21	0.25
	14	20.40	10.00	5.00	2.60	2.35
	18	10.23	5.40	2.74	1.36	4.60
	19	13.50	5.24	2.69	1.35	4.40
	21a	30.20	10.46	5.93	3.99	2.40
	21b	31.80	11.06	4.10	3.76	2.40
	24	30.10	12.09	6.19	3.44	3.00
	26	24.30	11.65	7.76	4.25	1.80
	28	17.86	5.84	2.83	1.63	4.00
	31	41.90	13.35	7.51	3.88	1.05
	33	23.53	16.07	9.23	5.55	0.60
	35	21.50	9.75	5.21	2.76	2.05
	38	20.61	11.74	6.08	4.03	1.00
	40	25.55	14.46	7.15	4.43	1.05
	42	26.98	8.72	4.72	2.68	2.00
	45	20.95	5.94	3.32	2.55	1.40
	47	20.79	9.42	4.91	3.26	2.80
	49	21.79	10.29	5.27	3.34	2.90
Sludge	21	29.00	11.55	4.79	2.90	2.53
	52	17.30	6.47	3.32	2.37	3.55

a,b are replicate samples

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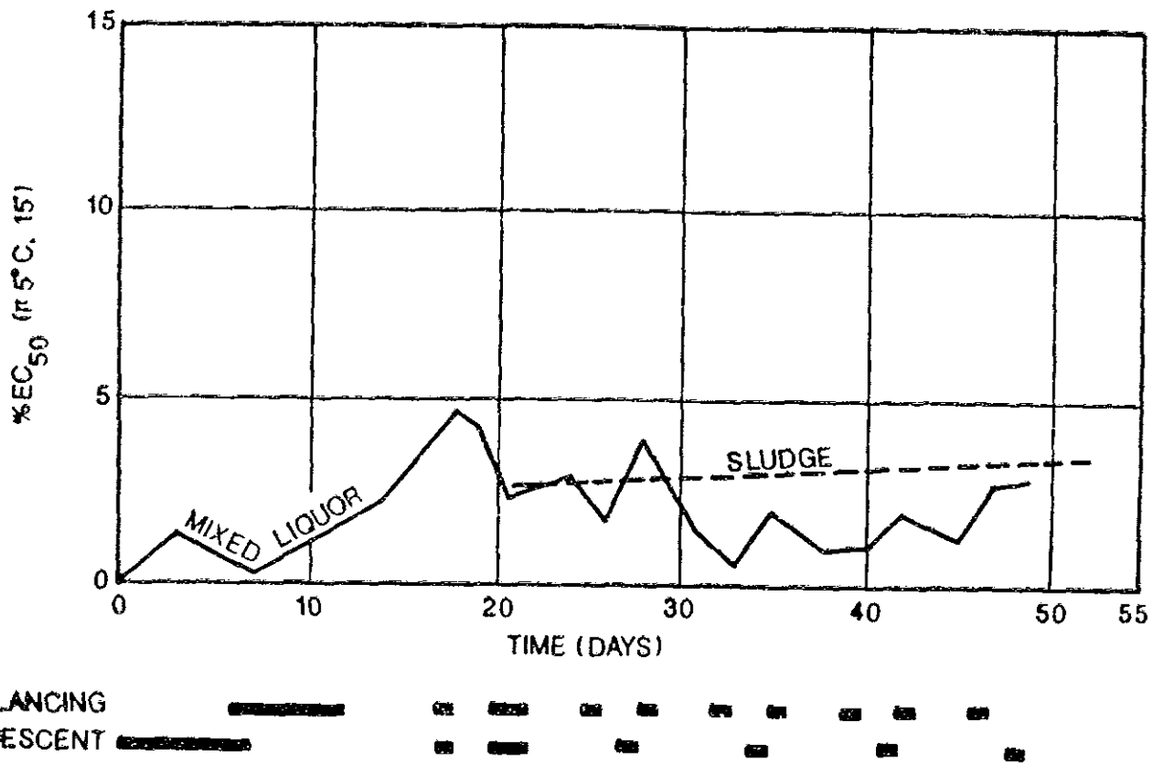

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FIGURE 6-1
MICROTOX ANALYSIS
VESSEL 1

DRAWN BY:	DATE:	PROJECT NO.
SJ	3-10-87	275-19

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TABLE 6-2

MICROBIOLOGICAL COUNTS (CFU/ml)
RELATIVE CATALASE ACTIVITY AND DISSOLVED OXYGEN (DO)
DURING BIODEGRADATION IS VESSEL 1

	Vessel 1		
Day	Plate Count CFUx10^7/ml	Bio Mass Catalase	DO (mg/l)
0	0.019	2.00	NA
4	NA	4.69	NA
7	0.026	3.94	NA
11	0.001	NA	NA
12	0.14	NA	NA
14	0.14	NA	NA
18	0.54	8.00	NA
19	6.6	8.15	NA
21	23.3	>10	NA
24	18.7	3.26	NA
25a	21.3	3.05	NA
25b	16.6	6.13	NA
26	16.9	5.13	NA
27	15.4	3.66	NA
28a	12.4	1.30	NA
28b	7.6	6.80	NA
31	17.5	4.50	NA
32	11.9	7.32	0.6-0.5[c]
33	20.4	7.46	0.5
34	8.2	5.10	0.6-0.
35a	10.1	3.25	6.0
35b	8.9	8.46	4.0
36	2.9	5.27	1.5
37	13.6	5.43	0.5
38	11.7	6.44	0.6-5.1
39	32.0	6.35	5.1-2.1
40	25.4	7.49	4.9-4.7
42	29.9	6.80	7.4-5.2
45	35.5	6.58	6.9-7.3
46	30.5	5.20	7.6-5.2
47	40.5	5.24	7.8-8.3
48	43.5	5.35	7.2-7.6
49	57.5	5.75	7.6

a. Sampled after 12 hr, statis, but before air lancing
b. Sampled after air lancing
c. Morning - afternoon measurements

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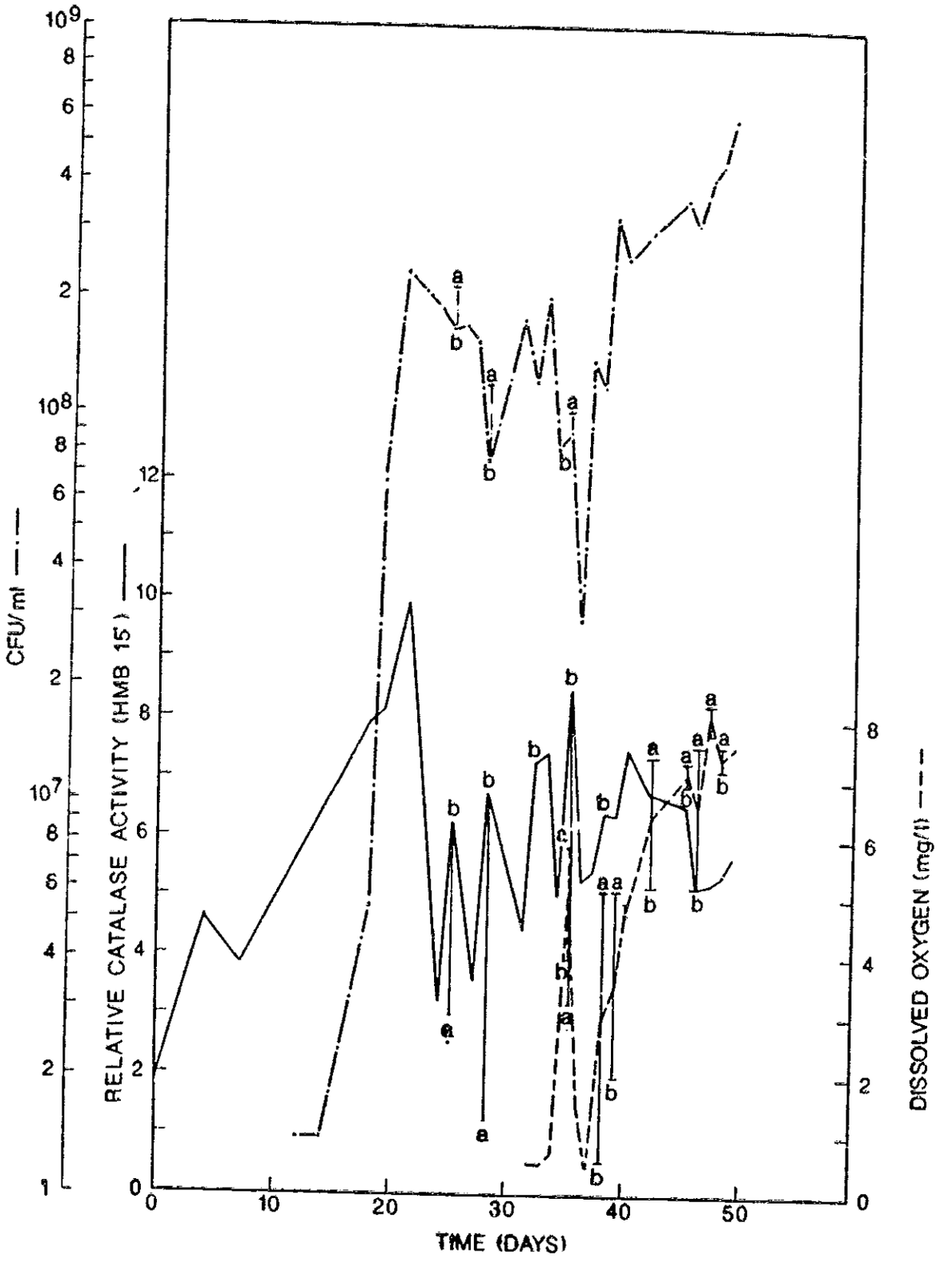

a = After 12 hours static

b = After air lancing

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FIGURE 6-2
BIOLOGICAL EVALUATION
VESSEL 1

DRAWN BY	DATE	PROJECT NO
SJ	3-10-87	275-19

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6.2 Inorganic and Wastewater Treatment Parameters from Vessel 1

Analytical values for seventeen inorganic and five wastewater treatment parameters are summarized in Table 6-3. The eight RCRA metals (As, Ba, Cd, Cr, Pb, Hg, Se, Ag) were found in concentrations near the level of detection. Slight variations in concentrations were observed over the nine sampling periods but no clear trends were evident. Copper concentrations fluctuated with time but had an average concentration of 4.0 mg/l. Both sulfate and chloride concentrations increased twofold during the sampling period. Phosphate, nitrate, and Total Kjeldahl Nitrogen (TKN) showed wide variations in the initial samples. Subsequent samples were filtered prior to analysis but this failed to narrow the variation observed. A weighted estimate provided the following average values:

DTKN	549.3 mg/l
DNO_3	27.9 mg/l
DPO_4	1.7 mg/l

Potassium concentrations were consistent and increased slightly in the last sampling periods.

Chemical Oxygen Demand (COD) correlated well with oil and grease analyses. Both analyses were reasonably consistent with major increases during the anoxic period, Day 21 through Day 28. The sixfold increase in COD during this period was probably due to substrate reduction by facultative anaerobic organisms during oxygen limiting conditions. Biological Oxygen Demand (BOD), Total Organic Carbon (TOC), and Total Suspended Solids (TSS) values were inconsistent and exhibited wide variations.

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TABLE 6-3

INORGANIC AND WASTEWATER TREATMENT PARAMETERS FOR BIODEGRADATION OF SLUDGE IN VESSEL 1 (MG/L)

Vessel 1	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	BOD	COD	TSS	TOC	O&G	OTKN*	TKN	NO_3*	PO_4*	SO_4	Cl^-	Ca	K
0	0.004	<1.0	<0.1	<0.3	0.47	<0.003	0.003	<0.1	825	5158	1137	1300	548	27.9	5.0	25.8	0.65	327	222	1.1	36.2
3	<0.003	<1.0	<0.1	<0.3	<0.3	0.005	0.003	<0.1	960	4047	646	1422	441	NA	5.0	24.2	0.71	314	285	0.9	98.7
7	<0.608	<1.0	<0.1	<0.3	<0.52	<0.002	<0.003	<0.1	409	5659	1227	1706	609	712	39	207	0.12	371	315	1.5	84.6
14	0.004	16.6	<0.10	2.2	6.5	0.034	0.008	<0.1	841	5037	3070	1844	174	500	NR	35.5	0.37	483	370	8.5	93.8
21	0.059	16	<0.10	2.1	5.2	0.016	<0.003	<0.1	NR	32900	3116	1759	1582	853	NA	43.8	37.0	495	365	15.1	106.2
28	0.009	<1.0	<0.1	<0.2	0.48	<0.003	<0.003	<0.05	394	33728	30	463	3158	15.3	433	1.10	105	460	387	1.14	92.5
35	<0.003	<0.5	<0.05	<0.20	<0.30	<0.0025	<0.003	<0.05	239	6003	56	2340	822	406	NA	1.58	23.4	480	450	0.45	90.6
42	0.007	0.6	<0.05	0.22	<0.30	<0.0025	<0.003	<0.05	96	2400	219	363	331	14	NA	10.4	2.86	280	133	<0.20	117.4
49	0.027	3.6	<0.05	1.74	3.19	0.024	<0.003	<0.05	720	16507	1850	1450	952	560	NA	227	5.71	610	540	7.73	145.0

NA - Not Analyzed
NR - No Results
* - Soluble Fraction Only

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6.3 Organic Components of Sludge and Mixed Liquor from Vessel 1

The volatile priority pollutant profile for Vessel 1 is shown in Table 6-4. The highest levels of most priority pollutant volatiles were detected 7 days after loading, about the time when mixing and recirculation problems in the reactor were resolved. Volatiles decreased rapidly from this point to a level less than 0.3% of the Day 7 concentration in 42 days. Chlorinated hydrocarbons account for more than 90% of the compounds in most samples. Their decrease in concentration correlates well with the increase in chloride concentrations discussed in Section 6.2.

The concentration profiles of base and neutral extractables for Vessel 1 are summarized in Table 6-5. Most of the compounds in this group are polynuclear aromatics (PNA). The total concentration of base/neutral extractables in the mixed liquor increased during the first 28 days of incubation, then decreased to 11.0% of the maximum level. The relatively low solubility of these high molecular weight PNAs may explain the apparent increase in concentration in the mixed liquor with time. Many microorganisms produce detergents and surfactants to improve substrate concentrations in their environment. As many of the readily degradable components are consumed, microorganisms exhibit a metabolic shift or population shift to address the more degradation-resistant substrates. This would explain the apparent increase in PNA concentration in the mixed liquor followed by a sharp decrease. Several compounds that appeared for the first time on Day 21 (chrysene, benzo(a) anthracene) are probably intermediates in the degradation pathway of more complex compounds. Of the entire sludge mass available for biodegradation, less than 20% of the compounds appear on our priority pollutant scan. Therefore, mass balance interpretations using the list are inappropriate.

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TABLE 6-4

Volatile Priority Pollutant Profile

During Biodegradation of Sludges in Vessel 1

	Initial	Days 0	3	7	14			21		28		35		42		49	
	Sludge	Mix	Mix	Mix	Liquid	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge
VOLATILES	ug/gm	ug/l	ug/l	ug/l	ug/l	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm
COMPOUND																	
Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acrylonitrile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloroethylvinyl ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis(chloromethyl)ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromomethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorodifluoromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl chloride	ND	160	190	ND	40	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroethane	ND	310	290	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene chloride	250	510	330	1100	110	ND	9	ND	ND	ND	28	94	89.6	100	ND	85	85
Trichlorofluoromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	220	290	ND	ND	75	ND	ND	ND	ND	6.8	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	220	920	780	13000	ND	250	8	71	ND	ND	23	ND	ND	ND	ND	ND	ND
trans-1,2-Dichloroethene	1630	6000	5300	38000	ND	1700	48	390	ND	270	160	65	35.7	66	ND	220	ND
Chloroform	8270	32100	29200	540000	3900	34000	600	5700	480	2900	2400	670	395	700	260	1260	380
1,2-Dichloroethane	ND	39100	32500	400000	6500	35000	480	8600	330	3400	2000	640	213	670	150	910	160
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.0	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	530	620	550	520	210	420	11	170	62	110	77	43	69.7	ND	54	58	65
Bromodichloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
trans-1,3-Dichloropropene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	350	670	620	880	270	440	13	170	ND	120	67	46	47.1	ND	ND	62	ND
cis-1,3-Dichloropropene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	690	4600	3700	5500	2900	2400	63	660	110	400	460	130	89.6	140	65	220	77
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromochloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	270	220	220	ND	76	130	4	78	ND	ND	52	ND	68.5	ND	57	ND	69
Toluene	970	1800	1900	2900	1200	1500	45	590	140	400	1500	130	196	130	160	220	200
Chlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	760	740	740	990	430	710	20	410	170	210	350	43	254	69	210	77	270
ND = Not Detected Below:	150	50	50	500	50	50	3.0	50	50	100	2.5	250	50	50	50	50	50

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TABLE 6-5

Base and Neutral Extractables Profile
During Biodegradation of Sludge in Vessel 1

BASE-NEUTRALS	Initial Sludge	Days 0	1	7	14			21		28		35		42		49	
		Mix	Mix	Mix	Liquid	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge
COMPOUND	ug/gm	ug/l	ug/l	ug/l	ug/l	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm
1,3-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
bis(2-Chloroethyl)ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
bis(2-Chloroisopropyl)ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitroso-di-N-propylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrobenzene	ND	240	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobutadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Isophorone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphtalene	610	1400	2200	9200	2.0	56000	2900	430000	4700	26000	309u	22u	340u	950	2700	2500	2000
bis(2-Chloroethoxy)methane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorocyclopentadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloronaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	110	240	340	1400	ND	ND	530	40000	600	10400	410	ND	ND	1900	530	890	440
Acenaphthene	ND	240	280	1700	ND	10000	560	37000	640	14400	430	51u	69u	2100	440	1300	390
Dimethylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	47u	55u	ND	ND	ND	ND
2,6-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	150	460	ND	2800	ND	ND	1200	89000	1300	26600	94u	100u	130u	3800	990	2400	890
4-Chlorophenylphenylether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Diphenylhydrazine	ND	4400	12000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Diethylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodiphenylamine	160	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	14u	14u	ND	ND	ND	ND
Hexachlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Bromophenylphenylether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	ND	160	240	1200	ND	ND	470	50000	590	11000	36u	34u	50u	2200	2000	2300	250
Phenanthrene	1147	1100	1400	7200	ND	41000	2400	210000	3200	68000	210u	180u	260u	3000	370	1800	1200
Di-n-butylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	ND	200	280	1700	ND	ND	ND	34000	540	8900	430	35u	47u	2600	270	2000	220
Pyrene	ND	260	360	2200	ND	13000	490	48000	680	8900	620	49u	82u	3700	620	5000	380
Benzidine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Butylbenzylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
bis(2-Ethylhexyl)phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND	210000	210	1200	11u	11u	16u	830	110	970	94
Benzo(A)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	1400	11u	12u	16u	860	110	900	100
3,3'-Dichlorobenzidine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-octylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(B)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(K)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	61	ND	ND	ND	ND	ND	ND
Benzo(A)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-C,D)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(A,H)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(G,H,I)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodimethylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ND = Not Detected Below:	100	100	200	1000	2.0	10000	400	250u	150	1000	60	10u	10	500	100	500	75

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Acid extractable and pesticide/PCB concentrations in the sludge and mixed liquor are summarized in Table 6-6. The only three phenolic compounds recorded were not found after Day 7. Heptachlor was the only pesticide detected during the first 14 days and again during the last 7 days. The latter may reflect inadequate sludge mixing since heptachlor appeared in the sludge on Day 42, then in the mixed liquor on Day 49.

The total volatiles, base and neutral extractables, acid extractables, and pesticide/PCBs found during biodegradation in Vessel 1 (Tables 6-4, 6-5, and 6-6) are summarized in Table 6-7. Total priority pollutant compounds reached their highest concentration in the mixed liquor 7 days after loading then decreased to 8% of this level on Day 49. The percentage of sludge in the mixed liquor decreased 100-fold 35 days after loading, indicating that the highly soluble/easily suspendable compounds were gone, leaving more insoluble precipitates.

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TABLE 6-6

Acid and Pesticide Extractables Profile
During Biodegradation of Sludges in Vessel 1

	Initial	Days 0	3	7	14		21		28		35		42		49	
	Sludge	Mix	Mix	Mix	Liquid	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge
ACID EXTRACTABLES	ug/gm	ug/l	ug/l	ug/l	ug/l	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm
COMPOUND																	
2-Chlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitrophenol	ND	ND	780	1800	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	ND	1100	1200	1500	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	ND	ND	280	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
p-Chloro-o-cresol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,6-Dinitro-o-cresol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ND = Not Detected Below:	100	100	200	1000	4.0	20	800	5000	300	5000	75	250	50	500	200	1500	100
PESTICIDE EXTRACTABLES																	
COMPOUND																	
ZA-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
B-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
D-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
G-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlordane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4' -DDD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4' -DDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4' -DDT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dieldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan I	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan II	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan Sulfate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endrin Aldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor	ND	700	300	220	700	2800	ND	ND	ND	ND	ND	ND	ND	ND	3600	700	ND
Heptachlor Epoxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ND = Not Detected Below:	50	6	4	2	4.0	40	50	4	100	1000	10	100	1	75	25	30	10
Toxaphene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1016	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1221	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1232	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1242	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1248	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1254	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1260	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ND = Not Detected Below:	50	300	200	100	400	1000	50	1000	50	1000	10	100	1	75	25	30	10

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TABLE 6-7

TOTAL VOLATILES BASE AND NEUTRAL EXTRACTABLES,
ACID EXTRACTABLES, AND PESTICIDES/PCBs DURING BIODEGRADATION IN VESSEL 1

Mix (ug/l)	Day	Volatiles	Base/ Neutrals	Acid Ext.	Pesticides PCBs	Total
	0	87970	8800	1100	700	98570
	3	76610	17200	2260	300	96370
	7	1002890	27400	3300	220	1033810
	14	76625	120000	BDL	2800	199425
	21	16839	114800	BDL	BDL	283191
	28	7830	177300	BDL	BDL	185130
	35	1855	5580	BDL	BDL	7435
	42	1875	21940	BDL	BDL	23815
	49	3012	20060	BDL	700	23072

Sludge (ug/gm)	Day	Volatiles	Base/ Neutrals	Acid Ext.	Pesticides PCBs	Total	% Sludge Mixture
	0	13930	2177	BDL	BDL	16107	0.7
	14	1101	8550	BDL	BDL	9851	2.0
	21	1292	12460	BDL	BDL	13752	2.0
	28	7127.8	8661	BDL	BDL	15818.8	1.2
	35	458	10790	BDL	BDL	12248	0.01
	42	956	8140	BDL	3600	12696	0.02
	49	1226	5964	BDL	BDL	7190	0.03

BDL = Below Detectable Limits

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6.4 Air Emissions from Vessel 1

Analytical results for volatile and semi-volatile air emissions collected from the headspace of Vessel 1 are summarized in Table 6-8. Five PNA and three volatiles were present at detectable levels during operation of Vessel 1. All compounds generally decrease in concentration with time except on Day 39 when more vigorous than usual air lancing was conducted.

An estimate of the total amount of volatile and semi-volatile compounds released during the operation of Vessel 1 can be calculated by integration of the air sampling data over time. These values are summarized in Table 6-9.

6.5 Biological Evaluation from Vessel 2

Microtox gamma values and $\%EC_{50}$ for the mixed liquor and selected sludge samples from Vessel 2 are shown in Table 6-10 and are also shown in graph form on Figure 6-3. Toxicity of the mixed liquor decreased initially, increased, then decreased sharply until Day 18 when oxygen became limiting. The mixed liquor toxicity fluctuated for the next 17 days until air sparging provided sufficient dissolved oxygen at Day 35. Beginning at Day 35, toxicity fell consistently until operations were terminated. The toxicity of the sludge was reduced over 50% in the 31-day period beginning with Day 21.

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TABLE 6-8

AIR EMISSIONS COLLECTED WITH POF AND
CHARCOAL TUBES IN THE HEADSPACE OF VESSEL 1

DAYS

Date :	12/20	1/12	1/13	1/16	1/20	1/23	1/27	1/30	2/3	2/6	2/10	2/13
Sample Day :	-6	17	18	21	25	26	32	35	39	42	46	49
Sample Duration (hrs) :	4.00	8.00	4.00	4.00	6.00	6.00	4.00	6.97	6.50	7.00	6.60	4.00
PRIORITY POLLUTANTS SEMIVOLATILES (ppb)												
Sample Volume(l)	937.92	1786.56	852.00	885.00	1309.68	1425.24	912.67	1652.77	1524.90	1654.38	1548.02	936.00
Naphthalene	80.0	103.0	120.0	91.9	20.1	17.1	15.1	0.5J	9.1	0.58	0.10	0.20
Acenaphthylene	6.2	12.3	10.1	6.3	1.2	3.0	4.2	2.3	12.0	4.3	1.9	1.4
Acenaphthene	6.7	12.1	9.9	6.3	1.3	4.0	5.1	2.8	14.0	6.0	3.4	4.7
Fluorene	4.5	9.8	7.4	4.6	1.0	3.0	4.2	2.7	11.0	3.9	2.3	4.7
Phenanthrene	1.5	3.1	2.3	1.4J	1.0J	1.1	1.7	1.1	3.6	0.75	0.44	0.88
Anthracene	1.5U	0.6U	0.5J	1.5U	0.3J	0.3J	0.6J	0.3J	0.9	0.10	0.10	0.20
Fluoranthene	1.3U	0.7U	1.3U	1.3U	1.0U	0.8U	1.3U	0.7U	0.8U	0.10	0.10	0.20
Pyrene	1.3U	0.7U	1.3U	1.3U	0.9U	0.8U	1.3U	0.6U	0.8U	0.10	0.10	0.20
Benzo(a)anthracene	1.0U	0.6U	1.2U	1.2U	0.9U	0.8U	1.2U	0.6U	0.8U	0.10	0.10	0.20
Chrysene	1.0U	0.6U	1.2U	1.2U	0.8U	0.8U	1.2U	0.6U	0.7U	0.10	0.10	0.20
Benzo(b)fluoranthene	1.0U	0.6U	1.1U	1.1U	0.8U	0.7U	1.0U	0.6U	0.6U	0.10	0.10	0.20
Benzo(k)fluoranthene	1.0U	0.6U	1.1U	1.1U	0.7U	0.7U	1.0U	0.6U	0.6U	0.10	0.10	0.20
Benzo(a)pyrene	1.0U	0.6U	1.1U	1.1U	0.7U	0.7U	1.0U	0.6U	0.6U	0.10	0.10	0.20
Indeno(1,2,3-cd)pyrene	1.0U	0.6U	1.1U	1.1U	0.7U	0.7U	1.0U	0.6U	0.6U	0.10	0.10	0.20
Dibenzo(an)anthracene	1.0U	0.5U	1.0U	1.0U	0.7U	0.6U	1.0U	0.5U	0.6U	0.10	0.10	0.20
Benzo(ghi)perlene	1.0U	0.5U	1.0U	1.0U	0.7U	0.6U	1.0U	0.5U	0.6U	0.10	0.10	0.20
NON PRIORITY POLLUTANT SEMIVOLATILES (ppb)												
2-methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.1	1.3	1.8
Dibenzofuran	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.3	0.75	1.7
PRIORITY POLLUTANTS VOLATILES (ppm)												
Sample Volume(l)	47.47	89.76	46.32	47.04	74.52	77.65	48.49	86.28	79.37	84.38	82.98	49.15
Benzene	2.8	0.3	0.2	0.2	0.1	0.1	0.1	0.1U	0.3	B	B	B
Toluene	1.0	0.4	0.2	0.1	0.1U	0.1U	0.1U	0.1U	0.3	<0.04	0.08	0.23
Ethylbenzene	0.3	0.3	0.05J	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	<0.03	<0.03	<0.03
Trichloroethene	0.1U	ND	ND	ND	ND	ND	ND	ND	0.05E	ND	ND	ND
Tetrachloroethene	01.U	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3-Hexanone,2,2-dimethyl	ND	ND	ND	ND	ND	ND	ND	ND	1.5	ND	ND	ND

U = Undetected at listed detection limits.
J = Compound is present but below listed detection limit.
E = Estimated value.
B = Present in Blank.
ND = Not Detected.
NA = Not Analyzed.

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Table 6-9

SUMMARY OF THE PRIORITY POLLUTANT VOLATILES AND SEMI-VOLATILES LOST TO VOLATILIZATION IN VESSEL 1

	Sample Weighted[1] Total Lost To Volatilization (GRAMS)
Semi-Volatiles	
Naphthalene	4.23
Acenapthylene	0.50
Acenaphthene	0.56
Fluorene	0.44
Phenanthrene	0.16
Anthracene	0.02
Volatiles	
Benzene	61.8
Toluene	27.4
Ethylbenzene	9.1

[1] 56 day incubation period

Note: See Table 3, Page 16 in the "Amendment" Section of this report for explanation of the method used to calculate this data.

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TABLE 6-10

MICROTOX™ GAMMA VALUES AND
% EC_{50} FOR MIXED LIQUOR
AND SLUDGE FROM VESSEL 2 DURING BIODEGRADATION

		Dilution				
	Day	50%	25%	12.5%	6.25%	%EC_{50}
Mixed Liquor	-3	-	-	11.13	1.44	4.40
	-1	-	38.10	10.05	3.89	3.28
	0	4.35	3.31	2.23	1.53	2.50
	3	2.91	1.61	0.99	0.51	14.00
	7	4.27	2.96	2.22	1.38	3.10
	14	4.70	2.00	1.00	0.60	11.00
	18	4.15	1.02	0.42	0.23	21.50
	19	3.00	1.28	0.87	0.22	17.00
	21a	3.94	2.51	1.69	1.07	5.60
	21b	3.95	2.12	1.06	0.77	5.60
	24	4.51	2.80	1.78	1.26	4.20
	26	3.80	2.20	1.29	0.76	9.20
	28	3.31	1.42	0.79	0.54	14.50
	31	4.18	2.47	1.59	0.99	6.25
	33	6.06	3.48	2.26	1.39	4.00
	35	4.31	2.27	1.30	0.52	10.80
	38	2.72	1.59	1.01	0.45	13.60
	40	2.54	1.59	0.80	0.49	16.00
	42	2.80	1.68	1.00	0.59	12.50
	45	2.80	1.16	1.01	0.78	13.50
	47	2.34	0.95	0.53	0.35	23.30
	49	1.54	0.82	0.63	0.30	29.00
Sludge	21	2.35	4.52	3.12	1.73	3.30
	52	4.71	2.59	1.56	1.55	7.80

a,b are replicate samples

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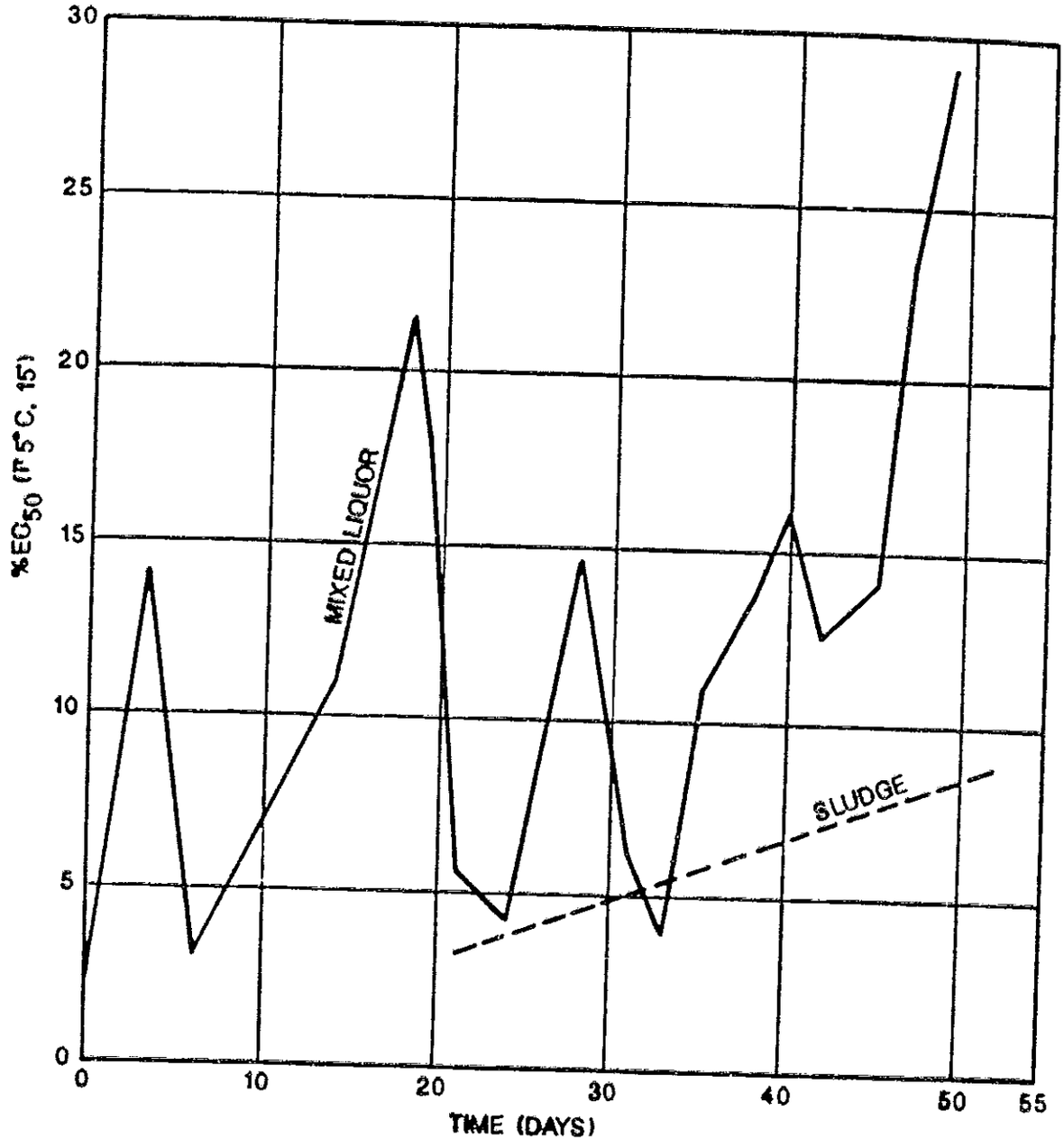

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FIGURE 6-3
MICROTOX ANALYSIS
VESSEL 2

DRAWN BY:	DATE:	PROJECT NO.
SJ	3-10-87	276-19

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Total colony forming units, relative catalase activity, and dissolved oxygen in Vessel 2 are summarized in Table 6-11 and are also shown in graph form on Figure 6-4. The concentration of microorganisms increased rapidly until 12 days after loading, reached a plateau for several days at 2 x 10^8 CFU/ml, then declined as oxygen became limiting at Day 18. The concentration remained relatively constant, near 8 x 10^7 CFU/ml, for the next 17 days until air sparging supplied sufficient dissolved oxygen to support the higher titer.

Catalase activity increased sharply in response to air lancing while the pre-lancing aquiescent period suppressed catalase activity. Catalase activity was consistently higher when dissolved oxygen was greater than 2 mg/l.

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TABLE 6-11

MICROBIOLOGICAL COUNTS (CFU/ml)
RELATIVE CATALASE ACTIVITY AND DISSOLVED OXYGEN (DO)
DURING BIODEGRADATION IS VESSEL 2

	Vessel 2		
Day	Plate Count CFUx10^7/ml	Bio Mass Catalase	DO (mg/l)
0	0.01	0	NA
4	NA	0	NA
7	1.76	0.5	NA
11	1.81	NA	NA
12	18.4	NA	NA
14	20.0	NA	NA
18	5.2	0.63	NA
19	4.4	0.83	NA
21	9.0	4.22	NA
24	6.7	0.70	NA
25a	2.7	0.52	NA
25b	4.5	2.79	NA
26	9.4	0.76	NA
27	8.5	0.95	NA
28a	6.3	0.38	NA
28b	9.7	4.50	NA
31	9.3	0.92	NA
32	9.2	4.16	1.0-0.6[c]
33	7.2	2.36	0.7-1.2
34	10.0	0.64	0.5-1.2
35a	2.2	0.49	6.0
35b	11.3	1.16	3.0
36	2.6	6.38	6.8
37	2.3	7.15	4.0
38	19.6	4.29	0.7-5.2
39	31.5	6.87	6.9-5.1
40	22.9	6.20	6.7-6.5
42	14.4	2.50	6.6-3.9
45	21.1	2.50	8.1-7.8
46	23.1	4.80	7.9-6.1
47	12.1	4.22	7.9-8.1
48	11.9	3.75	7.6-7.7
49	12.6	2.03	8.1

a. Sampled after 12 hr, statis, but before air lancing
b. Sampled after air lancing
c. Morning - afternoon measurements

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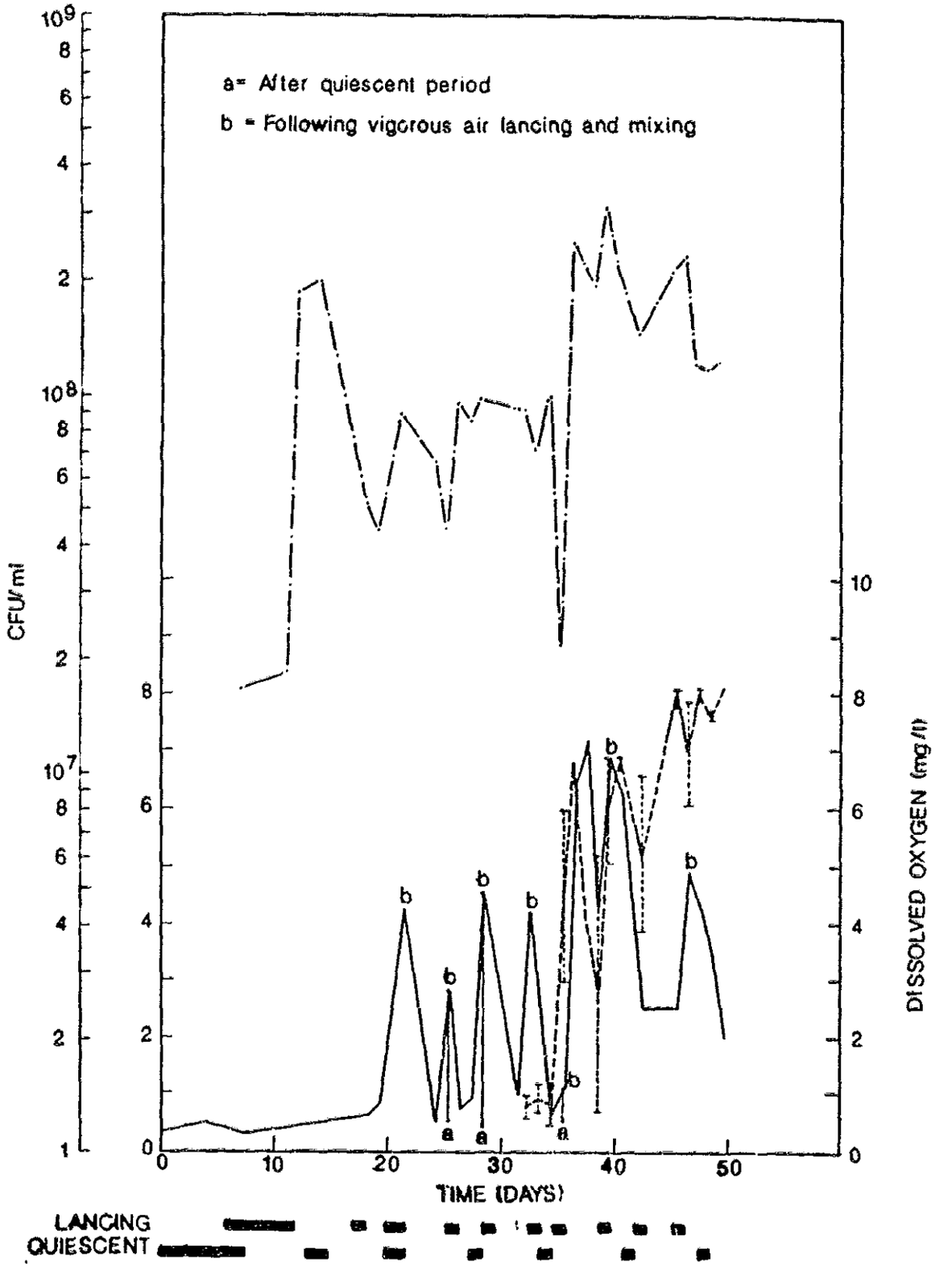

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FIGURE 6-4

BIOLOGICAL EVALUATION

VESSEL 2

DRAWN BY:	DATE:	PROJECT NO.
SJ	3-10-87	276-19

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6.6 Inorganic and Wastewater Treatment Parameters from Vessel 2

Of the 21 analyses of inorganic and wastewater treatment parameters monitored in Vessel 2 and summarized in Table 6-12, several clear correlations and trends are noteworthy. The concentration of the eight RCRA metals and copper fluctuated near the level of detection. The chloride and sulfate concentrations increased consistently until Day 42, then decreased. Nitrate, phosphate, and TKN were variable with estimated average values of:

D.TKN	46.70 mg/l
D.NO_3	13.00 mg/l
D.PO_4	1.94 mg/l

COD and O&G correlated well but BOD, TSS, and TOC were inconsistent and unrelated to other trends.

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TABLE 6-22

INORGANIC AND WASTEWATER TREATMENT PARAMETERS FOR SUPERNATANTS OF SLUDGE IN VESSEL 2 (MG/L)

Vessel 2	As	Ba	Cd	Cr	Pb	Hg	Se	Ag	BOD	COD	TSS	TOC	O&G	NH_3-N*	TKN	NO_3*	PO_4*	SO_4	Cl^-	Ca	K
0	0.003	<1.0	<0.2	<0.3	<0.3	<0.003	<0.003	<0.1	180	968	559	157	197	26.3	8.8	9.22	8.30	115	6	1.0	8.4
3	<0.003	<1.0	<0.1	<0.3	<0.3	<0.003	<0.003	<0.1	225	571	247	154	112	NA	52.1	4.87	24.1	112	99	<0.1	121.7
7	0.003	<1.0	<0.1	<0.3	<0.3	<0.003	<0.003	<0.1	319	1088	313	169	217	35.8	3.6	471	0.66	136	22	<0.1	10.2
14	0.003	5.2	<0.10	0.6	0.49	0.006	<0.003	<0.1	300	504	2850	220	667	74.5	NA	10.5	12.9	194	111	1.3	104.0
21	0.063	16	<0.10	2.0	1.6	0.011	<0.003	<0.1	NA	7566	112	219	1944	94.6	NA	31.8	1.52	203	115	5.7	126.3
28	0.003	7.36	<0.1	0.84	0.80	0.004	<0.003	<0.05	411	9920	6	1466	1015	81.3	36	4.78	43.8	241	130	1.89	117.1
35	<0.003	2.2	<0.05	<0.22	<0.30	<0.0025	<0.003	<0.05	110	1293	24	234	176	28	NA	5.65	3.01	240	253	0.53	121.6
42	0.014	1.5	<0.05	0.83	1.52	0.009	<0.003	<0.05	379	5840	964	1690	881	382	NR	28.0	3.25	530	400	<0.20	196.2
49	0.019	2.3	<0.05	0.48	<0.30	0.004	<0.003	<0.05	139	4047	880	459	647	14	NR	18.0	2.92	275	148	1.11	101.1

NA - Not Analyzed
NR - No Results
* - Soluble Fraction Only

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6.7 Organic Components of Sludge and Mixed Liquor from Vessel 2

Volatile priority pollutants measured during biodegradation in Vessel 2 are summarized in Table 6-13. The highest concentration of volatiles in the mixed liquor was observed 7 days after loading, then the concentration decreased to less than 1.5% of this level in 42 days. Even though chlorinated hydrocarbons account for less than 40% of the priority pollutant volatiles in Vessel 2, the chloride concentration consistently increased until Day 49 (see Table 6-12).

Base and neutral extractable (BNE) priority pollutants from mixed liquor and sludge of Vessel 2 are shown in Table 6-14. PNA compounds account for more than 97% of this group. The highest concentration of BNE was measured 28 days after loading. Measurable amounts then decreased to less than 0.3% of this level by Day 49. As the biodegradation progressed, additional compounds (e.g., chrysene, benzo(a)anthracene) were observed.

Only pentachlorophenol and heptachlor were found in the acid extractables and pesticides/PCBs fraction and these were below detectable limits 21 days after loading (Table 6-15).

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TABLE 6-13

Volatile Priority Pollutant Profile

During Biodegradation of Sludges in Vessel 2

		Days															
	Initial	0	3	7	14			21		28		35		42		69	
	Sludge	Mix	Mix	Mix	Liquid	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge
VOLATILES	ug/gm	ug/l	ug/l	ug/l	ug/l	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm
COMPOUND																	
Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acrylonitrile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloroethylvinyl ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis(chloromethyl)ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromomethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorodifluoromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl chloride	ND	120	45	86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene chloride	ND	12	ND	ND	11	ND	3.0	ND	ND	ND	5	ND	6.6	ND	ND	ND	3.8
Trichlorofluoromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	22	12	22	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	52	320	150	300	16	23	3.1	ND	ND	ND	ND	ND	ND	ND	2.6	ND	ND
trans-1,2-Dichloroethene	99	390	180	420	33	32	4.9	ND	ND	12	ND	ND	ND	12	3.7	ND	ND
Chloroform	7	240	52	100	130	25	8.3	ND	3.3	ND	2.5	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	15	170	50	75	610	140	22	ND	5.0	ND	2.7	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	62	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	29	130	65	120	13	17	2.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
trans-1,3-Dichloropropene	ND	16	ND	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	280	290	ND	380	41	58	8.3	22	4.9	28	2.9	12	3.7	20	9.7	13	3.4
cis-1,3-Dichloropropene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	110	850	370	780	97	92	15	28	6.0	14	3.0	11	2.8	31	14	18	5.8
1,1,2-Trichloroethane	8	15	ND	22	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromochloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	11	17	ND	23	ND	ND	ND	ND	ND	ND	ND	ND	2.0	ND	2.8	ND	ND
Toluene	180	810	580	1100	180	190	24	84	29	27	15	10	26.7	59	72	35	39
Chlorobenzene	11	28	19	31	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	340	710	540	960	180	210	25	93	65	ND	42	ND	98.7	12	190	ND	96
ND = Not Detected Below:	6	10	10	10	10	10	1.5	10	2.5	10	2.5	50	2.5	10	2.5	1	2.5

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TABLE 6-14

Base and Neutral Extractables Profile
During Biodegradation of Sludge in Vessel 2

BASE-NEUTRALS	Initial Sludge	Days 0	3	7	14			21		28		35		42		49	
		Mix	Mix	Mix	Liquid	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge
COMPOUND	ug/gm	ug/l	ug/l	ug/l	ug/l	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm
1,3-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND	ND	ND	460	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
bis(2-Chloroethyl)ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
bis(2-Chloroisopropyl)ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitroso-di-N-propylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobutadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Isophorone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	4100	300	ND	ND	ND	100	240	2800	430	3400	350	ND	330	ND	290	ND	520
bis(2-Chloroethoxy)methane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorocyclopentadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloronaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	800	ND	ND	ND	ND	ND	ND	940	40	1600	41	ND	50	ND	40	32	64
Acenaphthene	940	ND	ND	ND	ND	ND	ND	960	37	2120	33	ND	33	ND	25	ND	45
Dimethylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,6-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	1900	ND	ND	ND	ND	200	70	2400	89	4480	80	ND	97	ND	77	ND	150
4-Chlorophenylphenylether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Diphenylhydrazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Diethylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodiphenylamine	310	250	280	ND	ND	ND	91	ND	ND	ND	ND	110	160	ND	ND	ND	ND
Hexachlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Bromophenylphenylether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	730	ND	ND	ND	ND	100	ND	1280	50	1500	51	ND	50	ND	43	ND	66
Phenanthrene	3800	120	140	ND	ND	400	130	5900	210	10400	205	ND	190	75	147	ND	290
Di-n-butylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	700	ND	ND	ND	ND	100	ND	1200	34	1600	40	110	38	ND	30	ND	41
Pyrene	840	ND	ND	ND	ND	150	ND	2200	48	2740	56	120	75	170	46	53	104
Benzidine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Butylbenzylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
bis(2-Ethylhexyl)phthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	ND	ND	ND	ND	ND	ND	410	210	520	ND	ND	21	ND	110	ND	27
Benzo(A)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	470	ND	ND	14	ND	110	ND	ND
3,3'-Dichlorobenzidine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-octylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(B)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(K)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(A)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-C,D)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(A,H)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(G,H,I)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodimethylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ND = Not Detected Below:	200	100	100	600	10	0.1	50	400	25	500	20	100	10	75	25	30	25

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TABLE 6-15

Acid and Pesticide Extractables Profile
During Biodegradation of Sludges in Vessel 2

	Initial	Days 0	3	7	14			21		28		35		42		49	
	Sludge	Mix	Mix	Mix	Liquid	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge	Mix	Sludge
ACID EXTRACTABLES	ug/gm	ug/l	ug/l	ug/l	ug/l	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm	ug/l	ug/gm
COMPOUND																	
2-Chlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
p-Chloro-o-cresol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,6-Dinitro-o-cresol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pentachlorophenol	ND	150	110	ND	ND	1.9	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND
4-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ND = Not Detected Below:	200	100	100	600	2.0	0.2	100	1000	50	1.0	50	250	1	10	500	1500	200
PESTICIDE EXTRACTABLES																	
COMPOUND																	
Alpha-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beta-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Delta-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Gamma-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlordane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4' -DDD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4' -DDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4' -DDT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dieldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan I	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan II	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan Sulfate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endrin Aldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor	ND	3600	700	2900	4102	1200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor Epoxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ND = Not Detected Below:	50	4.0	4.0	2.0	4.0	4.0	50	1000	10u	0.4	10	100	10	500	50	100	50
Toxaphene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1016	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1221	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1232	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1242	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1248	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1254	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1260	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ND = Not Detected Below:	50	200	200	100	400	200	50	1000	50	40u	10	100	10	500	50	100	50

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The total volatiles, base and neutral extractables, acid extractables, and pesticide/PCBs found during biodegradation in Vessel 2 (Tables 6-13, 6-14, and 6-15) are summarized in Table 6-16. The percentage of sludge (based on the increased organic priority pollutants) in the mixed liquor increased gradually, reaching a maximum at 28 days after loading. A 100-fold reduction in solubility/suspendability was observed 35 days after loading and beyond.

6.8 Air Emissions from Vessel 2

Volatiles and semi-volatiles collected from the headspace of Vessel 2 are sumamrized in Table 6-17. All semi-volatile and volatile priority pollutants were below detectable limits during the operation of Vessel 2 except naphthalene which exceeded detectable limits during two sampling periods. Measurable amounts of five PNAs and three priority pollutant volatiles were recorded only during the loading of Vessel 2.

An estimated summary of the total quantity of volatile and semi-volatile compounds released to the atmosphere from Vessel 2 is shown in Table 6-18.

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TABLE 6-16

TOTAL VOLATILES, BASE AND NEUTRAL EXTRACTABLES,
ACID EXTRACTABLES AND PESTICIDES/PCBs DURING BIODEGRADATION IN VESSEL 2

Mix (ug/l) ppm	Day	Volatiles	Base/ Neutrals	Acid Ext.	Pesticides PCBs	Total
	0	4140	680	BDL	BDL	4820
	3	2063	420	150	3600	6233
	7	4439	BDL	130	700	5269
	14	787	1510	2	2900	5199
	21	227	18090	BDL	1200	19517
	28	81	28830	BDL	BDL	28911
	35	33	370	BDL	BDL	403
	42	134	245	BDL	BDL	379
	49	66	85	BDL	BDL	151

Sludge (ug/gm) ppm	Day	Volatiles	Base/ Neutrals	Acid Ext.	Pesticides PCBs	Total
	0	1142	14020	BDL	BDL	15162
	14	116	532	BDL	BDL	648
	21	175	1148	BDL	BDL	1323
	28	73	856	BDL	BDL	929
	35	141	1058	BDL	BDL	1199
	42	295	918	BDL	BDL	1213
	49	150	1309	BDL	BDL	1459

BDL = Below Detectable Limits

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TABLE 6-17

AIR EMISSIONS COLLECTED WITH RAF AND CHANDAL TUBES IN THE HEADSPACE OF VESSEL 2

DAYS

Date :	12/20	1/12	1/13	1/16	1/20	1/23	1/27	1/30	2/3	2/6	2/10	2/13
Sample Day :	-6	17	18	21	25	28	32	35	39	42	46	49
Sample Duration (hrs) :	4.00	8.00	4.00	4.00	6.00	6.00	4.00	6.97	6.50	7.00	6.50	4.00
PRIORITY POLLUTANTS SEMIVOLATILES (ppb)												
Sample Volume(l)	933.60	1741.92	908.40	920.40	1441.44	1423.44	926.65	1906.98	1545.96	1860.60	1583.04	951.36
Naphthalene	55.0	0.6J	6.5	5.4	0.9J	0.7J	1.4J	1.2U	0.3J	0.1U	0.1U	0.1U
Acenaphthylene	2.2	0.3J	0.8J	0.9J	0.3J	0.7J	0.7J	0.2J	0.2J	0.1U	0.1U	0.1U
Acenaphthene	1.7	0.3J	0.7J	0.7J	0.4J	0.7J	0.9J	0.5J	0.3J	0.1U	0.1U	0.1U
Fluorene	1.6	0.4J	0.7J	0.8J	1.1U	0.7J	1.1J	0.4J	0.5J	0.1U	0.1U	0.1U
Phenanthrene	0.7J	0.2J	0.3J	1.5U	1.0U	0.3J	0.4J	0.8U	0.2J	0.1U	0.1U	0.1U
Anthracene	1.5U	0.8U	1.5U	1.5U	1.0U	1.0U	0.3J	0.8U	0.9U	0.1U	0.1U	0.1U
Fluoranthene	1.3U	0.7U	1.3U	1.4U	0.9U	0.8U	1.3U	0.7U	0.8U	0.1U	0.1U	0.1U
Pyrene	1.3U	0.7U	1.3U	1.4U	0.9U	0.8U	1.3U	0.6U	0.8U	0.1U	0.1U	0.1U
Benzo(a)anthracene	1.0U	0.6U	1.2U	1.2U	0.8U	0.8U	1.2U	0.6U	0.7U	0.1U	0.1U	0.1U
Chrysene	1.0U	0.6U	1.2U	1.2U	0.8U	0.8U	1.2U	0.6U	0.6U	0.1U	0.1U	0.1U
Benzo(b)fluoranthene	1.0U	0.6U	1.1U	1.1U	0.7U	0.7U	1.0U	0.6U	0.6U	0.1U	0.1U	0.1U
Benzo(k)fluoranthene	1.0U	0.6U	1.1U	1.1U	0.7U	0.7U	1.0U	0.6U	0.6U	0.1U	0.1U	0.1U
Benzo(a)pyrene	1.0U	0.6U	1.1U	1.1U	0.7U	0.7U	1.0U	0.6U	0.6U	0.1U	0.1U	0.1U
Indeno(1,2,3-cd)pyrene	1.0U	0.1U	1.1U	1.1U	0.7U	0.7U	1.0U	0.6U	0.6U	0.1U	0.1U	0.1U
Dibenzo(an)anthracene	1.0U	0.6U	1.0U	1.0U	0.7U	0.6U	1.0U	0.5U	0.6U	0.1U	0.1U	0.1U
Benzo(ghi)perlene	1.0U	0.5U	1.0U	1.0U	0.7U	0.6U	1.0U	0.5U	0.6U	0.1U	0.1U	0.1U
PRIORITY POLLUTANT VOLATILES (ppm)												
Sample Volume(l)	47.76	95.52	45.60	46.32	70.56	74.12	46.47	82.64	75.97	79.76	76.38	47.28
Benzene	0.8	0.1U	0.1U	0.1U	0.1	0.1U	0.1U	0.1U	0.1U	B	B	B
Toluene	1.1	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.16	0.05	<0.04
Ethylbenzene	0.9	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	0.1U	<0.03	<0.03	<0.03
Trichloroethene	0.1U	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cyclohexane, methyl	0.6U	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene(1-methylethyl-)	1.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cyclopentane,1-ethyl-1-methyl	ND	ND	ND	ND	ND	ND	ND	ND	0.3	ND	ND	ND

U = Undetected at listed detection limits.
J = Compound is present but below listed detection limit.
E = Estimated value.
B = Process is Blank.
ND = Not Detected.

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Table 6-18

SUMMARY OF THE PRIORITY POLLUTANT VOLATILES AND SEMI-VOLATILES LOST TO VOLATILIZATION IN VESSEL 2

	Sample Weighted[1] Total Lost To Volatilization (GRAMS)
Semi-Volatiles	
Naphthalene	2.00
Acenapthylene	0.11
Acenaphthene	0.09
Fluorene	0.10
Phenanthrene	0.04
Anthracene	0.00
Volatiles	
Benzene	17.1
Toluene	27.8
Ethylbenzene	26.2

[1] 56 day incubation period

Note: See Table 3, page 16 in the "Amendment" Section of this report for explanation of the method used to calculate this data.

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7.0 CONCLUSIONS

7.1 Biodegradation

The Field Tank Biodegradation Test has confirmed the laboratory conclusions, that the French Limited sludges are biodegradable utilizing a liquid/liquid matrix of lagoon water and sludge.

Review of the analytical data reveals that a tenfold reduction of volatiles and base neutrals was achieved in Vessel 2, and a tenfold reduction of volatiles was achieved in Vessel 1.

The test experienced an interruption in the growth of the micro-organism population due to an unanticipated increase in oxygen demand when degradation of the more "difficult" high molecular weight compounds began. This occurred after an initial period when the lower molecular weight materials were being degraded. This interruption, combined with a delay in achieving a homogeneous sludge/water mix during the initial two weeks of the test, resulted in the sludge biodegradation being imcomplete at the end of the 49 day test.

Compounds on the priority pollutants list comprise approximately 20% of the total compounds present in the French Limited sludge and as a result most biodegradation activity is directed at other compounds. Since biodegradation intermediate compounds of priority pollutants and non-priority pollutants may or may not be on the priority pollutant list, measurement of the priority pollutants may exhibit an inconsistent degradation trend. Also, as degradation progresses consolidation of the remaining compounds may result in an apparent increase in concentration level even though their total quantity is decreasing.

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It was not possible to assess the progress of biodegradation based on sludge volume due to the following factors:

- The presence of major quantities of sand in the original sludge placed in the tank.
- The presence of a "soupy" biomass at the end of the test that could not be dewatered with the available facilities.
- Upon mixing with water the sludge volume increases due to hydration, and then, as degradation occurs the volume decreases.

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7.2 Air Emissions

Air emissions analysis data has identified the major priority pollutant volatile and semi-volatile compounds that were released from the biodegradation process. This information will be utililized in designing the air emissions program for the next biodegradation development step.

7.3 Operating Parameters

Results of biodegradation investigations in Vessel 1 and 2 indicates that certain analytical parameters are more essential to biodegradation optomization than others. Of the 21 inorganic and waste water treatment parameters measured, only COD, oil and grease, TKN, phosphate, and nitrate, would be useful in further studies. Inconsistencies in other parameters minimizes their application in future operation and control of biodegradation operations. Two additional parameters not measured in this study, but worthy of future consideration include Mixed Liquid Volatiles Suspended Solids (MLVSS) and Ammoniacal Nitrogen.

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Of the biological parameters measured in this study only Catalase would have application for future studies.

While the microbial count (CFU/ML) is informative, similar information can be obtained more rapidly with MLVSS. The microtox™ bioassay is useful for confirming loading rates and determining degradation end points but because of the interaction of mixed waste and its sensitivity to the endogenous end product, produces inconclusive data in high frequency analysis. Catalase measurement provides a rapid indication of microbial activity that intergrates the effect of mixing and dissolved oxygen.

Another observation based on review of the data indicates that organic analysis conducted to evaluate the progress of biodegradation should be based on a composite sample of hydrated sludge, rather than analysis of the sludge as it is obtained directly from the lagoon.

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8.0 RECOMMENDATIONS

The Laboratory Biodegradation Evaluation and the Field Tank Test results indicate that proceeding to the next step in the development of the French Limited Biodegradation Process is justified. The next development step should be directed at achieving the following objectives:

- Demonstrating the mechanics of how bio remediation of the lagoon would be accomplished.

- Defining the economics of the biodegradation remedial alternative.

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Environmental Health & Safety

April 24, 1987

Mr. R. E. Hannesschlager
U.S. Environmental Protection
Agency, Region VI
1445 Ross Avenue
Dallas, Texas 75202-2733

Dear Mr. Hannesschlager:

Attached you will find our response to the EPA and TWC comments on the "Field Evaluation of Biodegradation at the French Limited Site (Phase II) Volume 1" report.

We appreciate your prompt attention in preparing the agency's comments, and the discussion of our response comments in the meeting of April 22, 1987 with EPA and CH_2M Hill representatives. Please contact me if there are any questions.

Very truly yours,

R. L. Sloan
Special Projects Manager

RLS/kac

Arrachment

cc: Alex Onjanow (TWC)
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A Division of Atlantic Richfield Company

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ERT Response to EPA Comment on
"Field Evaluation of Biodegradation
at the French Limited (Phase II) Volume I"

EPA General Comments:

Biogradation may have occurred in the tanks; however, the same type of results could possibly result from air stripping due to air lancing and sparging operations. Headspace sampling of the tanks was performed and this indicated that volatiles were being released, but air sampling was not performed during air lancing operations and it is unclear if air sampling was performed during air sparging. Finally, no "rate-of-release" measurements were performed.

The reduction in base/neutral extractable in tank No. 2 could have been due to biodegradation; however, the data indicates some losses due to volatilization. In addition, without sludge volume (dry weight basis) measurements, the reduction in base/neutral extractables cannot be accurately calculated and the reduction of these contaminants may be due to a change in sludge character resulting in dilution of contaminants rather than degradation.

Preliminary review of the split sampling data indicates the presence of PCBs in tank No. 2 but not found in ERT's laboratory results. PCBs in the sludge sampling ranged from "Not detected" (day 14) to 74,000 ug/L (2/13/87 sampling) with no indication of PCB biodegradation.

Difficulties with mixing and the ability to obtain representative samples, and laboratory QA/QC may have accounted for some apparent reduction in contaminants. For example, air lancing for mixing did not start until day 12 of the testing and as discussed in previous meetings, the ability to mix the

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contents of the tanks increased as the operator become more experienced. The representativeness of sampling seems dependent on when air lancing occurred, when air sparging was taking place, extent of sludge settleability, and physically how the sample was taken. The relationship between these sampling variables are not presented in the ERT report. The methodology should be reviewed to assess the sampling and analytical errors of the biodegradation work.

In general, the discussions presented in the report are not sufficient to explain what is occurring. This needs to be expanded throughout the report. Estimates and conclusions must be supported by calculations and/or data which are presented in the report.

ERT Response: The general comments address four aspects of the test. These are air stripping, mass balance calculations, PCB concentrations, and the issue of sample representativeness and consistency. ERT response is as follows.

Air Stripping

Air stripping did remove some degree of the priority pollutants present in the sludges, and thus contributed to their reduction which was measured analytically. However, explanation of the analytical results based on air stripping alone is unlikely. Air samples of 4-8 hour duration were collected immediately following lancing operations, while air sparging and tank circulation continued. Based on these air analyses, ERT's best estimate of total priority pollutants lost to air stripping is well below

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both qualitative and quantitative analytical results. See Table 3 (page 16) in this response report for more detailed comment.

Mass Balance Calculations

Three factors that affect mass balance calculations for this system are sludge volume, sludge density and cumulative air emissions. The error associated with measurement of each of these factors precludes the ability to perform a meaningful mass balance calculation. Additionally, the calculation is not required to verify biodegradation. The biodegradation process can be verified by attainment of the decontamination criteria in the final solids residue and water. Obviously, while in operation, the biodegradation process must maintain acceptable air emissions limits.

PCB Concentrations

ERT is uncertain as to how to comment on the PCB analysis data. ERT's contract laboratory, Southern Petroleum Laboratories (SPL) reported no PCB's. NUS analyses reports three different PCBs in different sampling events (PCB 1232, 1242, and 1248) (see the following Tables 1 and 2). Of the twelve samples reported to contain PCBs, all but two of the concentration results reported were at the detection limit. Consultation with NUS indicates that separation of these

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TABLE 1

PCB DATA SUPPORT FROM MUD SAMPLE SPLITS, VESSEL 1

		DAYS															
		0	3	7	14			21		28		35		42		49	
	Initial Sludge ug/kg	Mix —	Mix —	Mix ug/l	Liquid ug/l	Mix ug/l	Sludge ug/kg	Mix ug/l	Sludge ug/kg	Mix ug/l	Sludge ug/kg	Mix ug/l	Sludge ug/kg	Mix ug/l	Sludge ug/kg	Mix ug/l	Sludge ug/kg
PCB-1016 a	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1221 a	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1232 a	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1242 a	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1248 a	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND b	ND	ND b	ND	ND b
PCB-1254 b	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND b	ND	ND b	ND	ND b
PCB-1260 b	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND b	ND	ND b	ND	ND b
a	13,000	NA	NA	30	10	10	40,000	10	19,000	10	24,000	10	25,000	10	9,100	10	20,000
b	13,000	NA	NA	10	10	10	20,000	10	4,600	10	1,200	10	2,500	10	1,300	10	4,900

NA = Not Analyzed

ND = Not Detected

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TABLE 2

PCB DATA SUPPORT FROM MIS

SAMPLE SPLITS, VESSEL 2

		DAYS															
		0	3	7	14			21		28		35		42		49	
	Initial Sludge ug/kg	Mix	Mix	Mix ug/l	Liquid ug/l	Mix ug/l	Sludge ug/kg	Mix ug/l	Sludge ug/kg	Mix ug/l	Sludge ug/kg	Mix ug/l	Sludge ug/kg	Mix ug/l	Sludge ug/kg	Mix ug/l	Sludge ug/kg
PCB-1016 a	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1221 a	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1232 a	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	23	36,000	ND	74,000
PCB-1242	29,000	NA	NA	36	ND	64	ND	180	23,000	ND	13,000	3,300	ND	ND	ND	ND	ND
PCB-1248 a	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	2,300	ND	ND	20	ND
PCB-1254 b	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1260 b	ND	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
a	29,000	NA	NA	36	44	10	63,000	180	23,000	10	13,000	3,300	2,300	23	36,000	10	74,000
b	1,300	NA	NA	10	10	10	5,500	10	1,200	10	1,300	270	130	10	7,600	10	5,000

NA = Not Analyzed

ND = Not Detected

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three PCBs on the chromatograph is very difficult, and subject to interpretation by the operator.

Differences in PCB extraction and sample clean-up methods could possibly provide an explanation for the variation in PCB analyses observed in the sludges. Soniatron extraction was the initial extraction method used by both laboratories. NUS utilized the fluorcil column cleanup method specified in EPA SW 846. Southern Petroluem Laboratories tested the sludges according to the ASTM method for oily samples but did not use a fluorcil column cleanup. Dan Difeo of SPL indicated that a mass of material eluted in the PCB range but background interferance precluded the clear identification of any specific PCB arochlor. Neither laboratory conducted a second column confirmation analysis.

The 1986 Field Investigation and Supplementary R.I. Report provided a total of 61 PCB analyses on triplicated samples from 22 locations in the lagoon. PCB 1242 was the only compound reported at that time.

Sample Representativeness

The early mixed liquor sample representativeness was variable, depending on the degree of mixing that was occurring at the time of sampling. However, beginning with day 14, the mixed liquor

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sample was collected 1 hour after lancing during continuous circulation and air sparging. The sampling procedure for the bottom sludges was revised to stop circulation and allow the tanks to settle overnight, prior to obtaining a bottoms sludge sample the next morning. Once this approach was instituted the representativeness of both mixed liquor and bottom sludge samples appears to be very good.

In an actual biodegradation operation it would be inappropriate to attempt to correlate mixed liquor priority pollutant analysis with biodegradation progress. However, upon completion of biodegradation, both the water and the bottoms residue should meet the decontamination criteria.

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SPECIFIC EPA COMMENTS

EPA Comment Section 2: Specific treatment objectives should be added to assess the ability of the testing to biodegradate the priority pollutants. None were presented in this Section.

ERT Response: The objective of the field test was to achieve a scale-up of the laboratory test; to define the operating parameters appropriate for control of the biodegradation process; and to verify that the biodegradation progress could be achieved within the available time. Specific treatment objectives were not established because achieving those objectives is a function of time.

EPA Comment: Section 2: The reduction in toxicity as measured in the Laboratory Evaluation of Biodegradation Report does not necessarily verify "excellent" biodegradation. Sampling and laboratory methodology and laboratory QA/QC were not available for review to confirm the test results. Metal results indicate that the data was poorly presented. Dilution factors need to be explained. The tables indicate metal biodegradation. This does not occur.

ERT Response: Another objective of the test was to ascertain whether the toxicity measurement would show a correlation with priority pollutant analyses and, thus be a useful indicator parameter. We agree that reduction in toxicity alone, would not verify excellent biodegradation. However,

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the reduction in toxicity measurement does correlate with the priority pollutant analysis, which shows a reduction in priority pollutant concentration.

The priority pollutant analyses were performed in accordance with same EPA approved procedures that were utilized in the 1986 remedial investigation.

The data presented in the report was a direct report of lab results. Consideration of the dilution factor that occurred as a result of preparing the initial sludge load into each laboratory test container would account for the decrease in metal concentrations reported in Table 8-6. We agree that biodegradation of metals does not occur.

EPA Comment Section 5: A description of how the sludge for the BOD test was acclimated to the lagoon environment was not described. Acclimation is very important to obtaining representative BOD results.

ERT Response: The BOD test was conducted in accordance with the EPA accepted procedure provided by Poly-Bac Corporation. This method incorporates a mixture of lyophilized bacteria which is well suited for routine BOD analysis.

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EPA Comment Section 6: The mixing techniques and sampling procedures were changed during the course of the study. This needs to be discussed in detail and a thorough discussion on how this affects the comparison of data needs to be presented.

ERT Response: Sampling procedures were consistent throughout the study. Mixed liquor samples were obtained using a 5-gallon bucket sampler. Sludge samples were taken using a piston sampler. Beginning on day 14 the tanks were allowed to settle overnight so that discrete samples of each phase (liquor and sludge) could be obtained the next morning.

We agree that mixed liquor samples may be affected by the degree of mixing occurring at the time of sampling. After day 14 the mixed liquor samples were consistently taken one hour after the water or air lancing operation while recirculation mixing was maintained.

EPA Comment Section 6: If the test was run for 49 days how do you obtain day 52 results?

ERT Response: The tanks were allowed to settle for 3 days after cessation of aeration and circulation before taking the final sludge sample for toxicity analysis. The final sludge priority pollutant sample was taken with a piston sampler on day 49, to be consistent with prior sampling protocol.

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EPA Comment Section 6.1: The data does not indicate that the percent EC-50 between 0 and 5 percent is statistically significant to conclude reduced toxicity or significant biodegradation. Supporting data and confidence interval calculations should be provided for review.

ERT Response: The plots of toxicity analysis shown on Figures 6-1 and 6-3 were presented to look for correlations with quantative chemical analyses. They were not intended to stand alone. A replicate analysis, performed on the day 21 samples, showed no difference in the EC-50 number.

EPA Comment Section 6.1: The discussion of the catalase system response to air injection and quiescent periods is possible but data is not presented to support conclusions.

ERT Response: In ERT's opinion, the discussion of the catalase system response to air injection and quiescent periods is a reasonable interpretation of the available data. There is strong correlation between catalase activity and air lancing as shown on Table 6-2 and 6-11, as well as Figures 6-2 and 6-4.

EPA Comment Section 6.2: If testing has stopped on day 42, the twofold increase in chlorides and sulfate would not be true. Sampling and analytical variability may have more impact on conclusion and the data variations may not be statistically significant.

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ERT Response: We agree with the comment, and review of the data causes ERT to suspect that the day 42 samples of the two tanks were inadvertantly interchanged. This suspicion is consistently supported by all of the waste water treatment parameter results reported for the two tanks, for this sampling event.

EPA Comment Section 6.2: If an increase in COD took place between day 21 and 29 during anaerobic conditions, why did COD increase on day 49 under aerobic conditions? Please provide explanation.

ERT Response: We see no apparent explanation.

EPA Comment Section 6.3: If testing had stopped on day 42, the correlation between chlorides and volatile removals does not hold. Data may not be statistically significant to reach this conclusion.

ERT Response: See comment in Section 6.2 regarding the day 42 samples.

EPA Comment Section 6.3: Data is not presented to support the conclusion that the increased in base/neutral contaminants is due to degradation intermediates. Sampling and analytical variability may lead to apparent but not realistic conclusions. In addition, the objective of the biodegradation tests would be to reduce priority pollutants. A mass balance of priority pollutants is needed to more fully assess the success of biodegradation on the lagoon contents.

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ERT Response: This is a reasonable explanation since new priority pollutant compounds such as chrysene and benzo(a)anthracene were not found in early sludge samples, but they did appear when PAH became the predominate substrate.

REFERENCE:

Rochkind, M.L., J.W. Blackburn and G.S. Sayler 1986. Microbial Decomposition of Chlorinated Aromatic Compounds. Hazardous Waste Engineering Research Laboratory, Cincinnati, OH EPA/600/2-86/090

The test was performed based on using the priority pollutant analyses of the final residue as a verification of biodegradation, and data sufficient to support a mass balance calculation was not obtained.

Mass balance analysis requires accurate determination of sludge volume and density. Sludge volumes were estimated to be 790 and 580 gallons ± 5% for vessels 1 and 2, respectively. Accurate density determination was complicated by the heterogenous nature of the sludge. Since the total priority pollutants comprise a relative small portion of the sludge, disappearance of most of the priority pollutants could be accounted for by the error factors. Mass balance calculations are insufficiently accurate to provide an estimate of priority pollutants losses in this system.

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EPA Comment Section 6.3: The reduction of contaminants presented in Table 6-7 is almost totally due to a reduction of volatiles. The data does not support biodegradation of volatiles which may have been reduced by air stripping.

ERT Response: In many biodegradation operations the more soluable, low molecular weight compounds will be degraded first, followed by the less soluable higher molecular weight compounds. Interpretation of data from the study confirms this saquance of events. We agree that a portion of the volatiles were air stripped, but it is unlikely that a major reduction in volatiles occurred through this mechanism.

A major thrust of the In-Situ Biodegradation Demonstration currently beginning, is to obtain data on this factor.

EPA Comment Section 6.4: Air emissions sampling does indicate a loss of volatiles and some semivolatiles during the operation of the tanks. Air emission rate measurements were not performed to estimate the loss of volatiles/semivolatiles through air sparging and lancing. This data is needed to assess the biodegradation test results before conclusions can be made about the successfulness of the tank tests.

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ERT Response: We agree that measurement of air emission rates is important to future understanding of the biodegradation process for the French Limited Site. While the data suggests that destruction of the priority pollutants was due to biodegradation, air stripping played a role in priority pollutant loss. There is insufficient data to prove beyond all doubt, the precise mechanism of priority pollutant loss.

EPA Comment Section 6.4: The data and methodology were not provided to review the results showing in Table 6-9. Calculations would be needed to review these results.

ERT Response: The equations used in these calculations are discussed in Table 3, attached.

EPA Comment Section 6.5: Same as 6.1.

ERT Response: See response to 6.1.

EPA Comment Section 6.6: Same as 6.2 relative to sampling and analytical variability.

ERT Response: See response to 6.2.

EPA Comment Section 6.7: The reasoning why the base/neutral extractables were reduced in Tank No. 2 and not in Tank No. 1 needs to be presented. The basic constituents of the sludge are similar and results would be expected to be similar. A tank to tank comparison would be helpful to explain the

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TABLE 3

Explanation and Calculations Supporting

Tables 6-9 and 6-18, Section 6: Analytical Results

Parameter	Equation	Example
Quantitative data in tables 6-8 and 6-17 is converted to ug/carton or P/F tube (T).	$ug/T = \frac{(ppm)(sample\ vol)}{\frac{24.45}{Compound\ MW}}$	Table 6-8 Date 12/20 Sample Day - 6 Benzene 2.8 ppm $ug/T = \frac{(2.8)(47.47)}{\frac{24.45}{78.12}}$ ug/T = 424.68
Determine ug released per day (D) in the sampled volume.	$ug/D = \frac{(ug/T)(24)(8)}{(sample\ duration\ hrs)}$	$ug/D = \frac{(424.68)(24)}{4.80}$ ug/D = 2548.08
Determine ug released per day in the vessel headspace (HS) volume.	$ug/D/HS = \frac{(ug/D)(HS\ volume)}{(sample\ volume)}$	Vessel HS vol = 378b0 liter $ug/D/HS = \frac{(2548.08)(378b0)}{47.47}$ ug/D/HS = 2031700.6 gm/D/HS = 2.03
Weight the emission rate by multiplying the number of days or interval (I) between sample events. An estimate of the total emissions by compound can be obtained by summation over the 56 day sampling period.	The interval from sample day -6 to day 17 was 23 days. gm/I/HS = (23) (2.03) gm/I/HS = 46.69	

NOTES:

Using the limited air sample database available, we calculated a concentration of each compound in the vessel headspace over time by using the sample volume, sample duration and the headspace volume.

These concentrations were summarized in Table 6-9 and 6-18. Obviously, the accuracy of these values is based on certain assumptions that may not be verifiable. For the purpose of making these estimates, we assumed that:

1. ...the headspace vapor was homogeneous;
2. ...the partial pressure of each compound in the headspace did not suppress emissions from the mixed liquor;
3. ...the headspace was essentially open space that did not accumulate vapors (This of course, was not the case, however, making this assumption would provide for higher concentrations than expected from an open top vessel);
4. ...the emission rate per day per headspace did not decrease during the interval following sampling (This is unlikely since air sampling began immediately after lancing and lasted only 4 to 8 hours. This assumption provides for the highest concentration estimate for each interval)
5. ...the emission levels observed at loading (Day -6) were maintained until the next sampling event (23 days).

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base/neutral extractable reduction in Tank No. 2. Sampling and analytical variability should be discussed as it relates to tank mixing, sampling methodology, laboratory QA/QC, and sludge/priority pollutant mass calculations. Data was not provided on reduction of solubility and suspendability observed on day 35.

ERT Response: The basic constituents of the sludge are not similar with respect to priority pollutant content, toxicity, and biodegradability as demonstrated in the laboratory bench scale tests and analytical reports from this study. The tanks were loaded at different rates, were amended using different supplements, and a different spectrum of organisms were present in each tank. Consequently, a tank to tank comparison is unrealistic.

The data showing reduction of solubility and suspendability observed on day 35 is presented in Table 6-16. The percent of sludge priority pollutants found in the mixed liquor after day 35 decreased 100 fold as compared to earlier samples. This was also observed in Tank 1 as shown in Table 6-7.

EPA Comment Section 6.8: Same as 6.4.

ERT Response: See response to 6.4.

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EPA Comment Section 7: General comments on the conclusions have been addressed earlier in this letter. However, several specific comments remain:

Sludge mass calculations and air emission rate measurements are extremely important to the evaluation of any biodegradation tests.

ERT Response: The biodegradation test for the French Limited Site can be evaluated by assuring that air emission rates remain within acceptable limits during operation of the system, and that priority pollutant analysis of the final residue meets the site clean-up criteria. Because the volume of sludges to be degraded is unknown, and the content of the sludges is so heterogeneous, mass balance calculations are not possible. See response to Section 6.3, above.

EPA Comment Section 7: How will reduced toxicity through the bioassay testing provide data on the degradation end points of priority pollutants?

ERT Response: Bioassay testing was conducted to evaluate the potential correlation with priority pollutant concentrations in the mixed liquor. Time and economical consideration favor the use of the bioassay as a rapid indicator of the loss of priority pollutants as compared to the time consuming and expensive GC/MS analysis. The bioassay would not replace final GC/MS analysis, but would be used as an indicator for the more extensive analysis.

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EPA Comment Section 7: How will the catalase measurement provide data on the degradation priority pollutant?

ERT Response: The catalase measurements is used as a process control parameter to evaluate the activity of the biological reaction mixture. This parameter is not intended to measure priority pollutant biodegradation results.

EPA Comment Section 7: An explanation of why the detection limits vary so much should be included. It is possible this is due to large concentrations of a compound which may mask other compounds which come off the gas chromotograph at a later retention time, but this should be explained in the report.

ERT Response: We agree with this possibility. However, quantitative non priority pollutant data for these samples are not available.

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Texas Water Commission Comments of
"Field Evaluation of Biodegradation
at the French Limited (Phase II) Volume I"

TWC Comment 1: The appendix states the laboratory reports are included? Where? We have not received them.

ERT Response: The Appendix volume was mailed April 15, 1987.

TWC Comment 2: Page 12, the statement "Meteorological conditions or persistent fog and rain prevented air sampling prior to day 17". This statement is inaccurate. Air sampling was requested by TWC/EPA and instituted after our insistence.

ERT Response: Tables 6-8 and 6-17, both report air data obtained from air samples taken during the first loading event for each tank. An air monitoring program was included in the initial plan for the tank test. Heavy rain and fog occurring during the initial weeks of the test resulted in conditions that, in the opinion of ERT, would preclude an accurate sample for analysis using normal sampling methods for Tenax and PUF cartridges. The TWC/EPA comment received during the field visit resulted in increased emphasis on the air monitoring program, and increased frequency of sampling. The fact that we experienced better weather from that point forward also was of help.

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TWC Comment 3: Section 4.4. Were these solids analyzed?

ERT Response: The solids removed from the tanks on day 52 were not analyzed. However, day 49 sludge samples which were analyzed, and reported in Tables 6-4, 6-5, 6-6, 6-13, 6-14, and 6-15 represent the same material.

TWC Comment 4: Table 6-3 only shows inorganic parameters in mixed liquor (mg/l). Where are the sludge or soil analyses? Section 6.2 is useless based on Table 6-3 as it exists.

ERT Response: The metal analyses presented in Table 6-3 were performed because biodegradation rates are affected by soluable metals in the mixed liquor. These metals and waste water treatment parameters were not intended to subsitute for sludge or soil priority pollutant analyses.

TWC Comment 5: Please explain the following (Page 27). "Of the entire sludge mass available for biodegradation less than 20% of the compounds appear on our priority pollutant scan. Therefore, mass balance interpretations using the list are inappropriate."

ERT Response: The 20% number is an estimate based on a total analysis of the sludges that was accomplished during the remedial investigation. Mass balance interpretations using this list are inappropriate because degradation intermediates of the non priority pollutants may appear on the priority pollutant scan.

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TWC Comment 6: Please provide explanation and calculations that support Table 6-9.

ERT Response: See Table 3 on Page 15.

TWC Comment 7: Table 6-4 shows drastic reduction in vinyl chloride, chloroethane, methylene chloride, chloroform, 1,2,-dichloroethane, etc., yet Table 6-8 lists only 6 volatiles picked up in the air sampling. What happened to all the other volatiles?

ERT Response: While the data suggests that destruction of the priority pollutants was due to biodegradation, air stripping played a role in priority pollutant loss. There is insufficient data to prove beyond all doubt, the precise mechanism of priority pollutant loss.

TWC Comment 8: Please explain and elaborate footnote for Table 6-9.

ERT Response: See Table 3 on Page 15.

TWC Comment 9: Section 6.6 is useless because it is based on Table 6-12. Same comment as # 4.

ERT Response: See response to TWC Comment 4.

TWC Comment 10: Table 6-17, with respect to Table 6-13, same comment as # 7.

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ERT Response: See Response to Comment 7.

TWC Comment 11: Please provide explanation and calculations for Table 6-18.

ERT Response: See Table 3 on Page 15.

TWC Comment 12: Tables 6-1, 6-10. Where does the sample from day 52 fit in during this 49 day test?

ERT Response: See response to EPA Comment Section 6.

TWC Comment 13: Conclusions (Section 7) are not supported by the data presented.

ERT Response: See Response to Comment 7.

TWC Comment 14: Please provide a mass balance interpretation for Vessel 2.

ERT Response: See response to EPA Comment Section 6.3.

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APPENDIX 1

FERROX BIODEGRADATION TIME CHART

VESSEL #1 (EAST)

OPERATING DAY/ DATE 86	END Reading	AMOUNT OF SLUDGE ADDED	AMOUNT OF pH CHEMICALS OR NUTRIENTS ADDED	HOURS OF CIRC.	HEATER OR AIR LANCING	AVG. BULK TEMP.	pH	Comments
-6/Dec. 20		520 gal		4 h		70°		All hot water circulation to Test Biodegradation Vessel, heaters on all night. Filled test vessel with 8,500 gal sea legoon water on 12/1/86.
-5/Dec. 21				10 h 40 m		68°		Hot water circulation to Test biodegradation vessels.
-4/Dec. 22				0 h		67°	5	
-3/Dec. 23			70 lb Dol. Limestone at 0815 80 lb Dol. Limestone at 0930	9 h 20 m		69°	0815.5 0930.6	
-2/Dec. 24		270 gal	120 lb Dol. Limestone at 1300	9 h 15 m		69°	0745.>6 0830.<7	
-1/Dec. 25			40 lb Dol. Limestone at 0800	7 h 30 m		76°	0800.5.5 0830.6	
0/Dec. 26			80 lb Dol. Limestone at 1200 80 lb Dol. Limestone at 1300 5.0 gal 4-11-11 12.0 gal 32-0-0	9 h		77°	0800.6 1300.6 1400.6.5	45# lb Limestone total has been added
1/Dec. 27				8 h 30 m		78°		
2/Dec. 28				8 h		79°		
3/Dec. 29				6 h 30 m		74°	0900.7 1500.7	
4/Dec. 30				7 h		79°	0930.7	
5/Dec. 31				4 h		79°	1200.7 1530.7	

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APPENDIX 1 (continued)

FRENCH BIODEGRADATION TIME CHART

VESSEL #1 (EAST)

OPERATING DAY/ DATE 87	BOD Reading	AMOUNT OF SLUDGE ADDED	AMOUNT OF pH CHEMICALS OR NUTRIENTS ADDED	HOURS OF CIRC.	METER OR AIR LANCING	AVG. BULK TEMP.	pH	COMMENTS
6/Jan. 1				6 h 30 m	Water lancing	74°	9700.7 1430.7	Tidal flooding stopped
7/Jan. 2				16 h	Water lancing	75°	9700.7	Chunks got smaller
8/Jan. 3				24 h	Water lancing	77°		
9/Jan. 4				24 h	Water lancing	74°	9400.7	Steam formed while lancing, large bottom deposits
10/Jan. 5				19 h 30 m	Water lancing	75°	1500.7	
11/Jan. 6				24 h	Water lancing	80°	9800.7 1640.7	
12/Jan. 7	3 before air lancing 50 during air lancing			24 h	Air lancing	85°	9800.7	Put water heaters on standby @ 0700. Steam formed after lancing, bad odor
13/Jan. 8				16 h		91°	7	
14/Jan. 9				11 h		70°	7	
15/Jan. 10				24 h		83°		
16/Jan. 11				24 h		84°	7	
17/Jan. 12	1-6			24 h		80°	7	Stack end of tank given highest BOD readings
18/Jan. 13	10 after air lancing			24 h	Air lancing	87°	7	
19/Jan. 14				24 h		87°	7	
20/Jan. 15				15 h	Water lancing	87°	7	Lanced to break up layer of scum
21/Jan. 16	20-40 1340 2-3 1430			12 h	Air lancing	77°	7	BOD readings taken after lancing

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APPENDIX 1 (continued)

FRENCH BIODEGRADATION TIME CHART

VESSEL #1 (EAST)

OPERATING DAY/ DATE 87	HNU Reading	AMOUNT OF SLUDGE ADDED	AMOUNT OF pH CHEMICALS OR NUTRIENTS ADDED	HOURS OF CIRC.	WATER OR AIR LANCING	AVG. BULK TEMP.	pH	COMMENTS
22/Jan. 17				24 h		79°	7	Some covers 1/2 of tank
23/Jan. 18	2-5			24 h		78°	7	
24/Jan. 19	1-2			24 h		73°	7	Turned heaters off at 0600
25/Jan. 20	1-2 before lancing 60 during lancing 2-3 1 h after lancing			24 h	Air lancing	73°	7	Less film on top in both tanks than before
26/Jan. 21	2-2.5			24 h		74°	7	Film covers most of tank
27/Jan. 22	0.5-1			15 h		73°	7	Put heaters on all night
28/Jan. 23	1-2 before lancing 15-17 during lancing 1-2 1 h after lancing			13 h 30 m	Air lancing	57°	7	Film is dissipating
29/Jan. 24	1			24 h		70°	7	
30/Jan. 25	1-2			24 h		70°	7	
31/Jan. 26	0.5-1			24 h		69°	7	Small amount of film north side
32/Jan. 27	0.7 @ 1200 16 @ 1330 5 @ 1335 0.5-1.0 @ 1435			24 h	Air lancing 1230-1330	73°	7	Dissolved oxygen (DO) DO = 0.6 mg/l @ 0830 DO = 0.5 mg/l @ 1435
33/Jan. 28	0.5-1.0			24 h		77°	7	DO = 0.5 mg/l. Installed air sparger; 10 cfm air compressor used for air supply.
34/Jan. 29	0.5			15 h		81°	7	DO = 0.6 - 0.8 mg/l Installed 100 cfm air compressor for sparger air supply. Compressor operated continuously.

007320

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APPENDIX 1 (continued)

FRENCH BIODEGRADATION TIME CHART

VESSEL #1 (EAST)

OPERATING DAY/ DATE 87	HNU Reading	AMOUNT OF SLUDGE ADDED	AMOUNT OF pH CHEMICALS OR NUTRIENTS ADDED	HOURS OF CIRC.	WATER OR AIR LANCING	AVG. BULK TEMP.	pH	COMMENTS
35/Jan. 30	1.5 @ 0830 2.5 @ 1330			14 h	Air lancing 1000-1200	78°	7	DO = 6.0 mg/l @ 0800 = 4.0 mg/l @ 1350
36/Jan. 31	1.0			24 h		76°	7	Air compressor malfunction @ 0800; repaired @ 0930 DO = 1.5 mg/l @ 1130.
37/Feb. 1	3.0			24 h		78°	7	Air compressor malfunction @ 0600 on 2/1/87; repaired @ 1230 on 2/2/87 DO = 0.5 mg/l @ 1030
38/Feb. 2	1.0-2.0			24 h		79°	7	Air sparging compressor put in operation @ 1250 DO = 0.6 mg/l @ 1100 = 5.1 mg/l @ 1350
39/Feb. 3	2 @ 1135 10 @ 1230			24 h	Air lancing 1035-1135	79°	7	DO = 5.1 mg/l @ 1000 = 4.0 mg/l @ 1035 = 0.5 mg/l @ 1135 = 2.0 mg/l @ 1250 = 2.0 mg/l @ 1545
40/Feb. 4	9-10			24 h		80°	7	DO = 4.9 mg/l @ 0930 = 2.6 mg/l @ 1015 = 4.7 mg/l @ 1400 Compressor shut down from 0945 to 1020; increased air flow to sparger at 1100
41/Feb. 5				15 h		80°	7	DO = 8.6 mg/l
42/Feb. 6	5 @ 0730 10 @ 1000 1.5 @ 1300			14 h	Air lancing 1000-1100	73°	7	DO = 7.4 mg/l @ 0730 = 5.2 mg/l @ 1300
43/Feb. 7	1.5 @ 1430			24 h		70°	7	DO = 5.7 mg/l @ 1430
44/Feb. 8	Baseline @ 1350			24 h	74°		7	DO = 6.1 mg/l @ 1350
45/Feb. 9	0.8-1			24 h		76°	7	DO = 6.9 mg/l @ 1030 = 7.3 mg/l @ 1700

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APPENDIX 1 (continued)

FRENCH BIODEGRADATION TIME CHART

VESSEL #1 (EAST)

OPERATING DAY/ DATE 87	HNU Reading	AMOUNT OF SLUDGE ADDED	AMOUNT OF pH CHEMICALS OR NUTRIENTS ADDED	HOURS OF CIRC.	WATER OR AIR LANCING	AVG. BULK TEMP.	pH	COMMENTS
46/Feb. 10	2.5 @ 1000 2.7 @ 1130 2.0 @ 1230			24 h	Air lancing 1000-1130	76°	7	DO = 7.6 mg/l @ 1000 = 5.2 mg/l @ 1230
47/Feb. 11	0.5-0.7		3 gal 32-0-0 5 gal 4-11-11	24 h		77°	7	DO = 7.8-8.3 mg/l
48/Feb. 12	Baseline			15 h		81°	7	DO = 7.2-7.6 mg/l
49/Feb. 13	HNU Malfunction			2 h		79°	7	DO = 7.6 mg/l @ 0930

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APPENDIX 1 (continued)

FRENCH BIODEGRADATION TIME CHART

VESSEL #2 (WEST)

OPERATING DAY/ DATE 86	BNU Reading	AMOUNT OF SLUDGE ADDED	AMOUNT OF pH CHEMICALS OR NUTRIENTS ADDED	HOURS OF CIRC.	WATER OR AIR LANCING	AVG. BULK TEMP.	pH	COMMENTS
-6/Dec. 20				2 h		55°		Filled West Biodegradation Vessel with 9200 gallons lagoon water 12/17/86
-5/Dec. 21		580 gal		8 h		70°		Hot water circulation to both biodegradation vessels
-4/Dec. 22								
-3/Dec. 23			1/2 gal phos. acid 1000 1/2 gal phos. acid 1100 1/2 gal phos. acid 1430	8 h 9 h 20 m		66° 64°	11 1000,11 1100,10 1430,10	
-2/Dec. 24			1/2 pt phos. acid 0930 1/2 pt phos. acid, 1300	9 h 15 m		67°	0930,9.5	
-1/Dec. 25				7 h 30 m		69°	0800,7 0830,7	
0/Dec. 26			10 gal 4-11-11	9 h		71°		
1/Dec. 27				8 h 30 m		74°		
2/Dec. 28				8 h		70°		
3/Dec. 29				6 h 30 m		72°	0800,7 1500,7	
4/Dec. 30				7 h		73°	0930,7	
5/Dec. 31				4 h		73°	1230,7.5 1550,8	

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APPENDIX 1 (continued)

FRENCH BIODEGRADATION TIME CHART

VESSEL #2 (WEST)

OPERATING DAY/ DATE 87	HND Reading	AMOUNT OF SLUDGE ADDED	AMOUNT OF pH CHEMICALS OR NUTRIENTS ADDED	HOURS OF CIRC.	WATER OR AIR LANCING	AVG. BULK TEMP.	pH	COMMENTS
6/Jan. 1				6 h 30 m		73°	0930,7.5 1430,7.5	
7/Jan. 2				16 h	Water lancing	74°	0900,7.5	
8/Jan. 3				24 h		77°		
9/Jan. 4				24 h		74°	0800,7.5	
10/Jan. 5				24 h	Water lancing	77°	1500,8	
11/Jan. 6			8 oz phos. acid at 0800 4 oz phos. acid at 1600	24 h	Water lancing	89°	0800,8 1030,7 1600,8	Total of approx. 2 gal. phos. acid added
12/Jan. 7	3 before air lancing 50 during air lancing			24 h	Air lancing	87°	0800,7	Put water heaters on standby @ 0700
13/Jan. 8				16 h		87°	7	
14/Jan. 9				11 h		76°	7	
15/Jan. 10				24 h		77°	7	
16/Jan. 11				24 h		78°	7	
17/Jan. 12	Baseline			24 h		80°	7	
18/Jan. 13	Baseline			24 h	Air lancing	81°	7	HND reading taken after lancing
19/Jan. 14				24 h		81°	7	
20/Jan. 15				15 h		87°	7	
21/Jan. 16	2-4 1340 Baseline 1430			12 h	Air lancing	75°	7	HND reading taken after lancing
22/Jan. 17				24 h		75°	7	

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APPENDIX 1 (continued)

FRENCH BIODEGRADATION TIME CHART

VESSEL #2 (WEST)

OPERATING DAY/ DATE 87	BMD Reading	AMOUNT OF SLUDGE ADDED	AMOUNT OF pH CHEMICALS OR NUTRIENTS ADDED	HOURS OF CIRC.	WATER OR AIR LANCING	AVG. BULK TEMP.	pH	COMMENTS
23/Jan. 18	Baseline			24 h		72°	7	
24/Jan. 19	Baseline			24 h		71°	7	Turned heaters oft at 0800
25/Jan. 20	Baseline before lancing 15 during lancing 1 one h after lancing			24 h	Air lancing	71°	7	Less film on top in both tanks
26/Jan. 21	Baseline			24 h		71°	7	Film is patchy; covers 1/4 of tank
27/Jan. 22	Baseline			15 h		69°	7	Put heaters on all night, film is dissipating
28/Jan. 23	Baseline before lancing 5-6 during lancing 0-1 one h after lancing			13 h 30 m	Air lancing	67°	7	
29/Jan. 24	Baseline			24 h		70°	7	
30/Jan. 25	Baseline			24 h		69°	7	
31/Jan. 26	Baseline			24 h		70°	7	No film
32/Jan. 27	Baseline @ 1200 10 @ 1320 2-3 @ 1335 <0.5 @ 1435			24 h	Air lancing 1230-1330	73°	7	Dissolved oxygen (DO) DO = 1 mg/l @ 0830 DO = 0.6 mg/l @ 1435
33/Jan. 28	Baseline			24 h		78°	7	DO = 0.7-1.2 mg/l Installed air sparger; 10 cfm air compressor used for sparger air supply

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APPENDIX 1 (continued)

FRENCH BIODEGRADATION TIME CHART

VESSEL #2 (WEST)

OPERATING DAY/ DATE 87	HNU Reading	AMOUNT OF SLUDGE ADDED	AMOUNT OF pH CHEMICALS OR NUTRIENTS ADDED	HOURS OF CIRC.	WATER OR AIR LANCING	AVG. BULK TEMP.	pH	COMMENTS
34/Jan. 29	Baseline			15 h		81°	7	DO = 0.5-1.2 mg/l Installed 100 cfm air compressor for sparger air supply. Compressor operated continuously.
35/Jan. 30	0.5 @ 0800 0.5 @ 1330			14 h	Air lancing 1000-1200	76°	7	DO = 6.0 @ 0800 = 3.0 @ 1330
36/Jan. 31	Baseline			24 h		76°	7	Air compressor malfunction @ 0800; repaired at 0930. DO = 6.8 mg/l @ 1130
37/Feb. 1	3.0			24 h		78°	7	Air compressor malfunction @ 0600 on 2/1/87; repaired @ 1210 on 2/2/87 DO = 4.0 mg/l @ 1030
38/Feb. 2	Baseline-0.2			24 h		79°	7	Air sparging compressor put in operation @ 1230 DO = 0.7 mg/l @ 1100 = 5.2 mg/l @ 1330
39/Feb. 3	10 above sparger 0.2 @ 1135; 0.5 @ 1230 elsewhere on top of vessel			24 h	Air lancing 1035-1135	79°	7	DO = 6.9 mg/l @ 1000 = 6.8 mg/l @ 1035 = 2.6 mg/l @ 1135 = 4.1 mg/l @ 1230 = 5.1 mg/l @ 1545
40/Feb. 4	Baseline			24 h		81°	7	DO = 6.7 mg/l @ 0930 = 5.7 mg/l @ 1015 = 6.5 mg/l @ 1490 Compressor shut down from 0945 to 1020
41/Feb. 5				15 h			7	DO = 8.8 mg/l
42/Feb. 6	Baseline @ 0730 40-50 @ 1000 Baseline @ 1300			14 h	Air lancing 1000-1100	71°	7	DO = 6.6 mg/l @ 0730 = 3.9 mg/l @ 1300

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APPENDIX 1 (continued)

FRENCH BIODEGRADATION TIME CHART

VESSEL #2 (WEST)

OPERATING DAY/ DATE 87	HNU Reading	AMOUNT OF SLUDGE ADDED	AMOUNT OF pH CHEMICALS OR NUTRIENTS ADDED	HOURS OF CIRC.	WATER OR AIR LANCING	AVG. BULK TEMP.	pH	COMMENTS
43/Feb. 7	Baseline @ 1430			24 h		70°	7	DO = 8.1 mg/l @ 1430
44/Feb. 8	Baseline @ 1350			24 h		74°	7	DO = 8.4 mg/l @ 1350
45/Feb. 9	Baseline			24 h		76°	7	DO = 8.1 mg/l @ 1030 = 7.8 mg/l @ 1700
46/Feb. 10	2.0 @ 1000 2.0 @ 1130 2.5 @ 1230			24 h	Air lancing 1000–1130	76°	7	DO = 7.9 mg/l @ 1000 = 6.1 mg/l @ 1230
47/Feb. 11	Baseline			24 h		77°	7	DO = 7.9–8.1 mg/l
48/Feb. 12	Baseline			15 h		81°	7	DO = 7.6–7.7 mg/l
49/Feb. 13	HNU Malfunction			2 h		79°	7	DO = 8.1 mg/l @ 0930

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DOCUMENT 275-17

LABORATORY EVALUATION OF BIODEGRADATION AT THE FRENCH LIMITED SITE

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Submitted to:

U.S. ENVIRONMENTAL PROTECTION AGENCY-REGION V:

AND THE

TEXAS WATER COMMISSION

Prepared for:

THE FRENCH LIMITED TASK GROUP

DECEMBER, 1986

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LABORATORY EVALUATION OF BIODEGRADATION AT THE FRENCH LIMITED SITE

1.0 INTRODUCTION

Several field investigations conducted at the French Limited site have resulted in a detailed understanding of the geology and hydrogeology of the site, as well as the chemical constituents of contamination present at the site. Initial planning for the site's feasibility study highlighted the lack of technical data regarding biodegradation technology, which is one of the important remedial action alternatives. As a result, the French Limited Task Group initiated a laboratory evaluation of biodegradation of the organic wastes at the site, including study of both sludges and contaminated soils.

This report describes the investigations performed, and their results. Recommendations for the next investigative step are also presented.

2.0 BIODEGRADATION STUDY METHODOLOGY

The methodology for performing the laboratory evaluation of biodegradation at the French Limited site was as follows:

- A quantity of French Limited lagoon sludges and contaminated soils was collected from four (4)

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locations. The sludge from three (3) of these locations contained a nearly colorless liquid, that was given the name "sludge supernatant."

- Extracts from the sludge, sludge supernantant, and contaminated soil were prepared.

- The relative toxicity of each extract was measured by adding the extract to lyophilized bacteria whose luminescence decreases upon exposure to toxicants. A Microtox™ toxicity meter was used to measure the change in bacterial light output, producing EC_{50} Microtox™ measurements of relative toxicity.

- The initial "loading rate" that could be used for biodegradation tests of each material, was then calculated based on each individual samples' relative toxicity. "Loading rate" is the amount of contaminant that can be mixed with water for the liquid/liquid tests, or mixed with soil for the semi-solid tests, without jeopardizing the viability of the degrading organisms.

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- Each contaminant was then mixed in proper proportion with French Limited soil extract which provided a source of micro organisms that were acclimated to the French Limited site chemistry.

- Each contamiant/soil mixture was then agitated for ten (10) days while extracting samples periodically for measurement of the relative toxicity. The progress of biodegradation was monitored by plotting the relative toxicity of the sample versus time.

- A matrix of contaminant materials were used to assess the impact of adding various types of fertilizers as nutrients for stimulating micro-organism activity.

- All of the preliminary experiments monitored changes in the relative toxicity of the reaction mixture by the Microtox™ bioassay and used this as an indicator of biodegradation activity. A final experiment used both Microtox™ and classical analytical chemical methods (gas chromatography, mass spectrography) to verify biodegradation of specific contaminants.

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3.0 CONTAMINANT MATERIAL PROCUREMENT

Test quantities of representative French Limited contaminant materials were obtained from four (4) locations around the perimeter of the lagoon as shown in Figure 3-1.

Contaminated surface soils were collected along the lagoon shore (using a shovel) at a depth of approximately six (6) inches. Corresponding sludge material was collected approximately ten (10) feet off-shore from the spot where the contaminated soil material was obtained. The sludge material was collected (from a boat) using a PVC plunger type sampler device, from the top 0-24 inches of sludge. Contaminant material procurement Locations #1 and #2 were located on the north and south sides of the lagoon, and Locations #3 and #4 at the east and west ends, respectively. The sludge and contaminated soil material obtained from each procurement site was composited from at least six (6), but not more than ten (10) PVC sampler or shovel fulls of material at each location.

The sludges from Locations #1, #2, and #3 were found to contain a slightly discolored liquid. It was decided that biodegradation tests would be conducted on this liquid separately from the sludge and the contaminated soil.

This contaminant material was given the name Sludge Supernatant.

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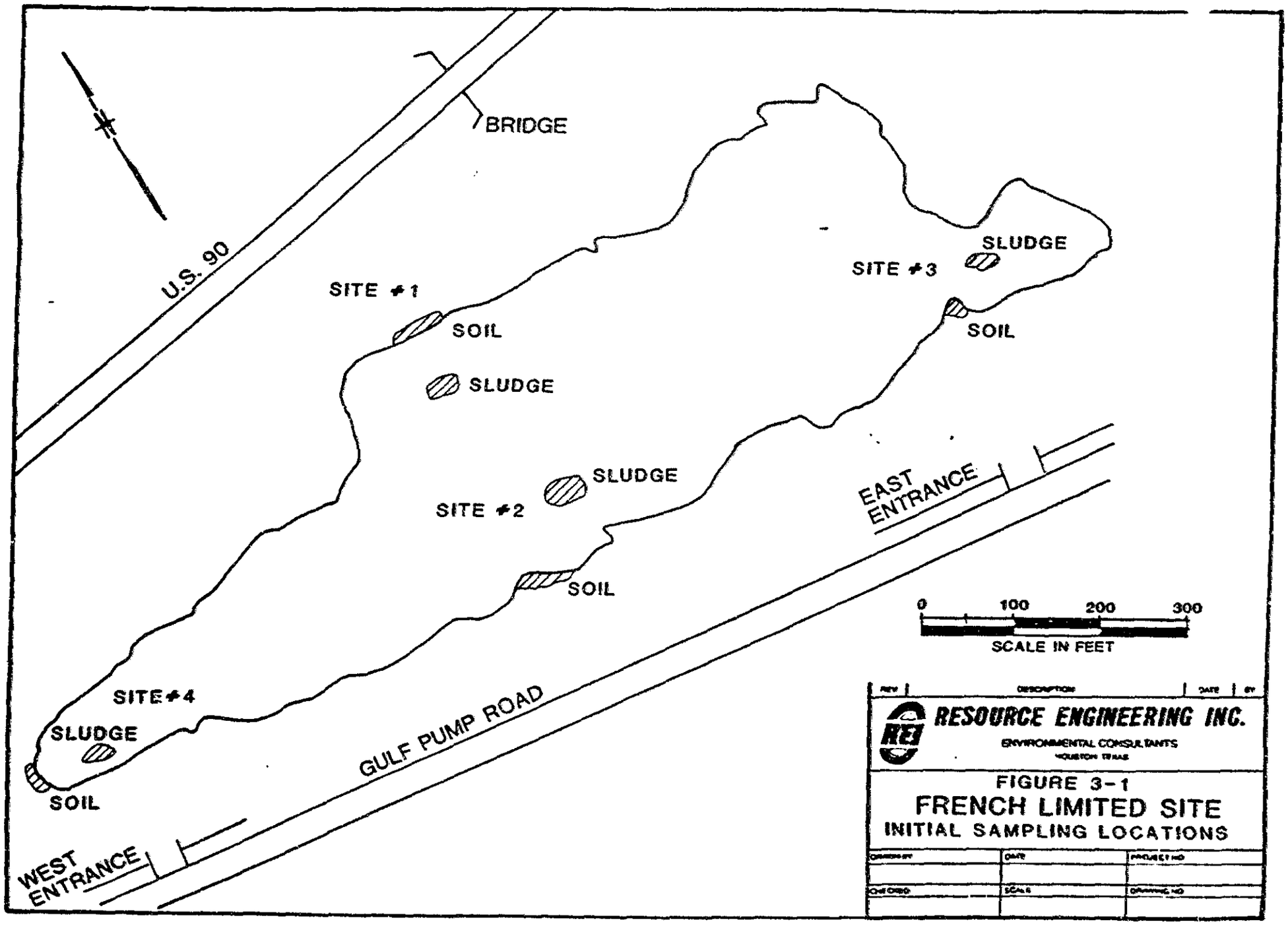
BRIDGE
U.S. 90
SITE #1
SOIL
SLUDGE
SITE #3
SLUDGE
SOIL
SLUDGE
SITE #2
EAST ENTRANCE
SOIL
SITE #4
SLUDGE
SOIL
GULF PUMP ROAD
WEST ENTRANCE
0 100 200 300
SCALE IN FEET
REV
DESCRIPTION
DATE
BY
RESOURCE ENGINEERING INC.
ENVIRONMENTAL CONSULTANTS
HOUSTON TEXAS
FIGURE 3-1
FRENCH LIMITED SITE
INITIAL SAMPLING LOCATIONS
DRAWN BY
DATE
PROJECT NO
CHECKED
SCALE
DRAWING NO

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4.0 LOADING RATE DETERMINATION

Based on the test procedure calling for mixing the various contaminant materials with water for the liquid/liquid tests and with uncontaminated soil for the semi-solid test, it was first necessary to determine the "Loading Rate" that could be used for each batch of contaminated material. This "Loading Rate" is defined as the quantity of contaminated material that can be mixed with water (or uncontaminated soil) for the bioderadation test, while still maintaining an active micro organism biomass.

This determination consisted of performing a three (3) step process.

- Prepare an extract from each contaminant material batch.
- Measure the relative toxicity of that extract.
- Determine each "Loading Rate", based on the measured relative toxicity data.

4.1 Extract Preparation - A known amount of contaminant material from each batch (one (1) gram (g) of sludge, or fifty (50) grams (g) of contaminated soil) was placed in a sealed flask with 400 milliliters (ml) of distilled water. The flask was mounted on a rotary shaker operating at 45 revolutions per minute (RPM) for 22 (± 2) hours at room temperature. The mixture was then allowed to settle and the extracts were

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separated from the insoluables by filtration using a Whatman #1 filter followed by a 0.45 micron millipore.

Sludge supernatant extract was not prepared by mixing and filtering. The supernatant was simply diluted to a 5% solution (by volume) with distilled water.

Two percent sodium chloride (NaCl) was added to adjust osmotic pressure of all extracts prior to the relative toxicity determination.

4.2 Relative Toxicity Measurement - The relative toxicity of each extract was determined using a method developed by the Microbics Corporation which measures light output from a bioluminescent marine bacterium. Their Microtox™ toxicity meter is equipped with a photomultiplier tube, a cooling system to maintain temperature at 15°C, and a digital display indicating light output. A lyophilized bioassay bacterium (Photo Bacterium Phosphoreum) which is a luminescent marine bacterium that exhibits decreasing light output upon exposure to toxicants, was obtained from Microbics Corporation for use in the relative toxicity measurements.

Ten microliters of lyophilized bacteria reconstituted with distilled water were added to 0.5 ml of 2% NaCl and placed in the cooling block at 15°C. When the light output had stablized, 0.5 ml of the sample to be tested was added and the change in light output measured after 5 mins. The change in luminescence was converted to a Gamma value where Gamma = light lost / light remaining. This relative toxicity test was then

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performed for several concentrations of extract, and the results documented by preparing a log-log plot of Gamma values versus the concentration of contaminat material. The results of these relative toxicity measurements are tabulated in Table 4-1 the same data is also plotted in graph form on Figures 4-1, 4-2, and 4-3 for contaminated soils, sludges, and sludge supernatant, respectively.

Essentially, all curves are straight, parallel lines. The relative toxicities for the four soil samples are #2 >> #3 > #4 > #1. The relative toxicity of the sludge and sludge supernatant material correlates well for each sample site. For the sludge and sludge supernatant samples, the relative toxicity is #3 > #1 > #4 > #2 and #3 > #1 > #2 respectively (sludge supernatant #4 was not tested). Based on relative toxicity measurements the sludge supernatant contains the extraction equivalent of about 20 g of sludge and therefore is considered to be significantly more toxic.

4.3 Loading Rate Selection - The EC_{50} value is defined as the concentration of contaminant material whose toxicity causes a 50 percent reduction in light output from the bacterium. This point represents a 50 percent change in bacteria activity and is the equivalent of a Gamma value of 1. It may be read directly off the log-log plots of Gamma values versus concentration of contaminant material shown in Figures 4-1, 4-2, and 4-3.

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TABLE 4-1

Gamma Values used for Determining EC_{50} and Loading Capacity of Soils and Sludges

	Gamma Values[a]			
	1.25	0.625	0.3125	(mg/ml)
Sludge 1	3.50	1.68	1.02	
Sludge 2	1.15	0.45	0.30	
Sludge 3	10.53	4.73	3.50	
Sludge 4	2.17	1.03	0.62	
	62.5	31.25	15.63	(mg/ml)
Soil 1	0.91	0.68	0.41	
Soil 2	23.09	14.30	6.38	
Soil 3	1.91	1.01	0.51	
Soil 4	1.36	0.67	0.39	
	5%	2.5%	1.25%	(% v/v)
Sludge Supernatant 1	5.32	2.80	1.48	
Sludge Supernatant 2	1.62	0.83	0.52	
Sludge Supernatant 3	41.89	12.93	8.17	

a. Illustrated in Figures 4-1, 4-2, and 4-3.

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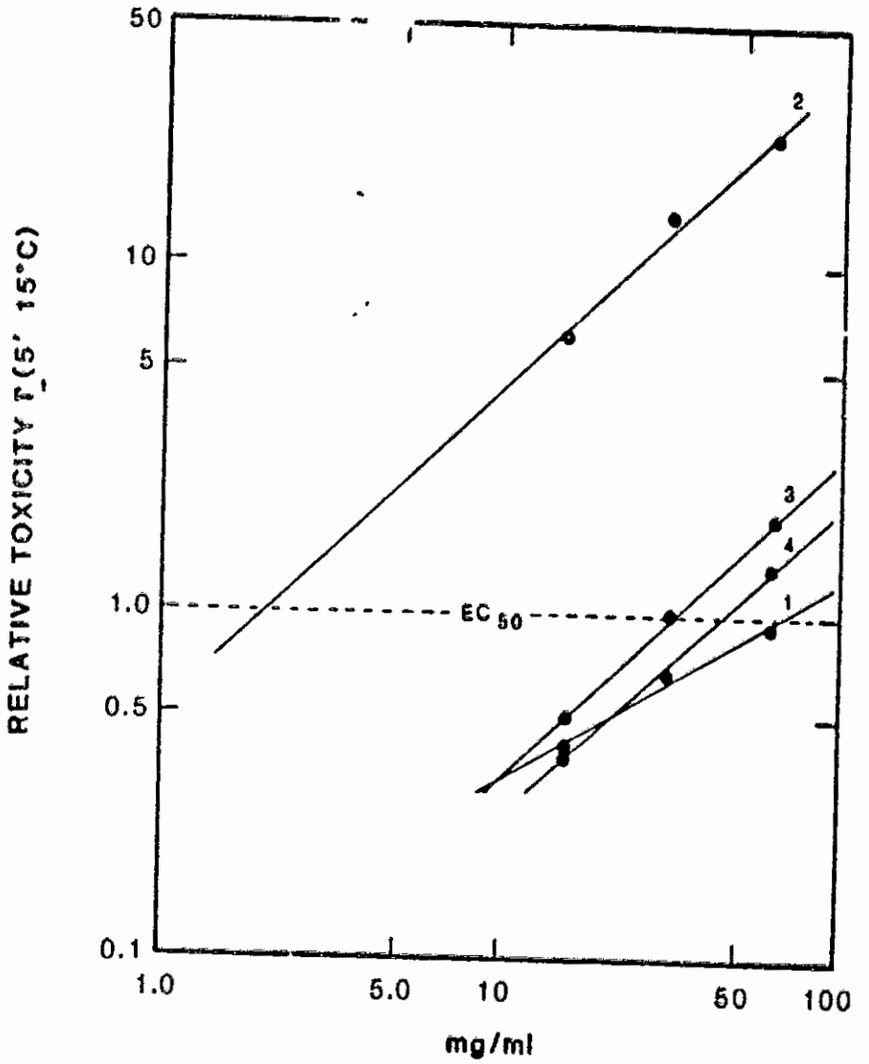

RESOURCE ENGINEERING
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FIGURE 4-1
RELATIVE TOXICITY AND EC_{50} OF SOIL FROM FOUR LOCATIONS
FRENCH LIMITED

DRAWN BY	DATE	PROJECT NO
L.M.G.	11-6-86	276-17

007345

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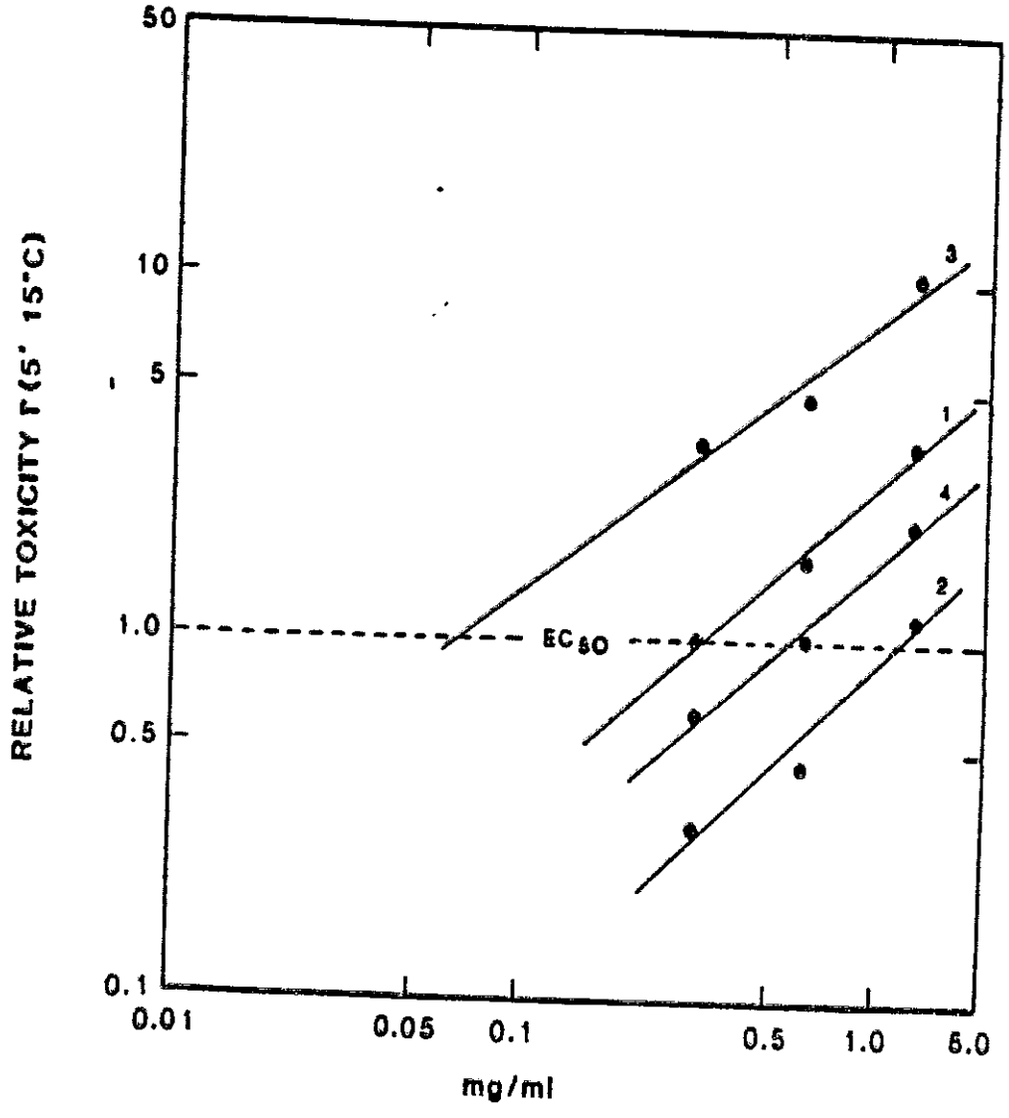

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FIGURE 4-2
RELATIVE TOXICITY AND EC_{50} OF SLUDGE FROM FOUR LOCATIONS
FRENCH LIMITED

DRAWN BY	DATE	PROJECT NO
L.M.G.	11-6-86	275-17

007346

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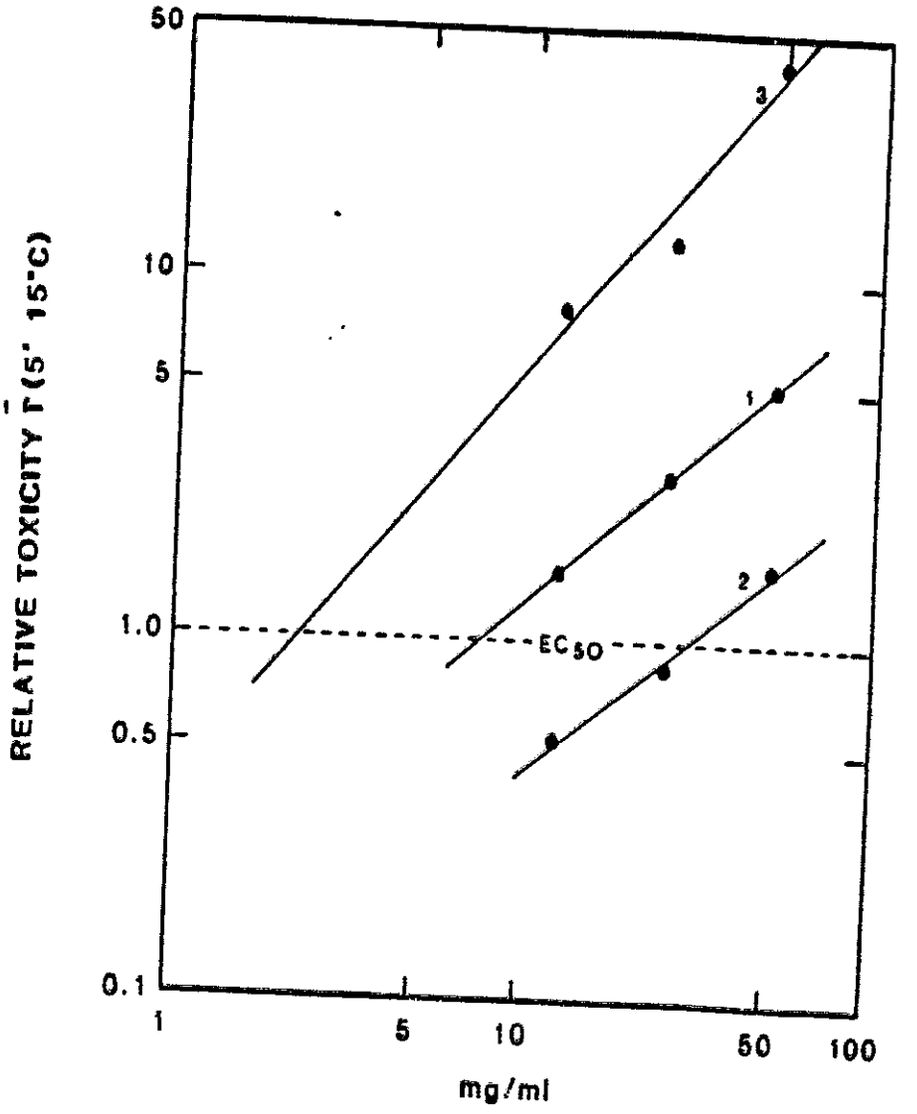

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FIGURE 4-3
RELATIVE TOXICITY AND EC_{50} OF SLUDGE SUPERNATANT FROM THREE LOCATIONS
FRENCH LIMITED

DRAWN BY	DATE	PROJECT NO
L.M.G.	11-6-86	276-17

007347

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The initital physical loading rates determined from the EC_{50} Microtox™ values for each sample are summarized in Table 4-2. For the corresponding sludge and sludge supernatants the percent loading rates are essentially the same. The 120% loading rate for soil material from Location #1 means that this sample can be degraded without dilution.

5.0 LIQUID/LIQUID BIODEGRADATION

5.1 Preliminary Supplements Tests - One (1) g of each sludge in 400 ml of water, was mixed with 100 ml of the corresponding soil extract (50 g in 400 ml) and the total volume made up to 800 ml with water. To assure adequate aeration, each sludge mixture was distributed at a rate of 100 ml per 1 liter flask. To 100 ml or each sludge mixture, 91 mg of 14-4-4 or 260 mg of 4-11-11 fertilizer was added; an unsupplemented 100 ml mixture was used as a control. This resulted in three (3) seperate flasks to be tested, for each location site, and a total of twelve (12) test flasks. The control and 2 treatment flasks for each sludge mixture were sealed then incubated at room temperature with shaking (45 rpm).

At times 0, 24, 48, 100 and 240 h after mixing, 5 ml was removed from each flask and tested for toxicity.

Table 5-1 provides a summary of the commerical fertilizer grades employed, their respective application rates in mg/100 g soil, and ppm N-P_2O_5-K_2O respectively.

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TABLE 4-2

Microtox™ Determination of EC_{50} and Physical Loading Capacity for Soil, Sludge and Sludge Supernatant

		EC_{50} mg/ml	Physical Loading Capacity %
Soil	1	75.00	120.00
	2	1.75	2.80
	3	31.00	49.60
	4	45.00	72.00
Sludge	1	0.30	0.48
	2	1.25	2.00
	3	0.09	0.014
	4	0.10	0.91
Sludge Super[a]	1	7.6%[b]	0.38
	2	28.0%	1.40
	3	2.3%	0.115

[a]Sludge supernatant was available only for sludges 1,2,3.

[b]Relative toxicities were determined on % v/v dilutions.

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TABLE 5-1

Summary of Commercial Fertilizer Grades
Used as Nutrient Supplements in
Biodegradation Experiments

Commercial Fertilizer Grade			mg/100 g Soil	Nutrients (ppm)		
N	P_2O_5	K_2O		N	P_2O_5	K_2O
14	0	0	71.0	100	0	0
32	0	0	109.4	350	0	0
32	0	0	1094.0	3500	0	0
19.4	19.4	0	180.4	350	350	0
14	4	4	91.0	128	37	37
6	12	6	83.0	50	100	50
4	11	11	260.0	104	286	286
12	12	12	41.0	50	50	50
0	24	12	41.5	0	100	50
0	4	4	41.5	0	17	17
0	4	4	166.0	0	68	68

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Sludge supernatant #2 was tested with the same fertilizer additions without dilution because this supernatant exhibited green chorophyilic coloration.

Figures 5-1, 5-2, 5-3, 5-4, and 5-5 illustrate the decrease in relative toxicity with respect to time for sludge material #1, #2, #3, #4, and sludge supernatant #2 in the presence of 4-11-11 and 14-4-4 fertilizer, respectively. These curves were plotted from the test results data which is also presented in tabular form on Table 5-2. In all cases, except sludge #4, no change in toxicity was observed in the absence of fertilizer; indicating that loss of toxicity was not due to physical loss of the toxicants. Sludge #4 exhibited a slight decrease in toxicity in the absence of fertilizer, however, this is relatively minor compared to that observed in the presence of fertilizer. All of the sludge mixtures except #3 and sludge supernantant #2 exhibit the best degradation kinetics with fertlizer 4-11-11. The two exceptions have better degradation rates with 14-4-4. Sludge samples #2, #3 and supernatant #2 (Figure 5-2, 5-3, and 5-5) exhibit changes in the degradation rate with time; suggesting that different compounds are degraded at different stages of the biodegradation.

5.2 Specific Supplements Tests - Mixtures of sludges #1, #2, and #3 were prepared for biodegradation as described in Section 5.1. To five flasks containing 100 ml of the sludge/soil mixture, 41 mg of 12-12-12 was added; no nutrients

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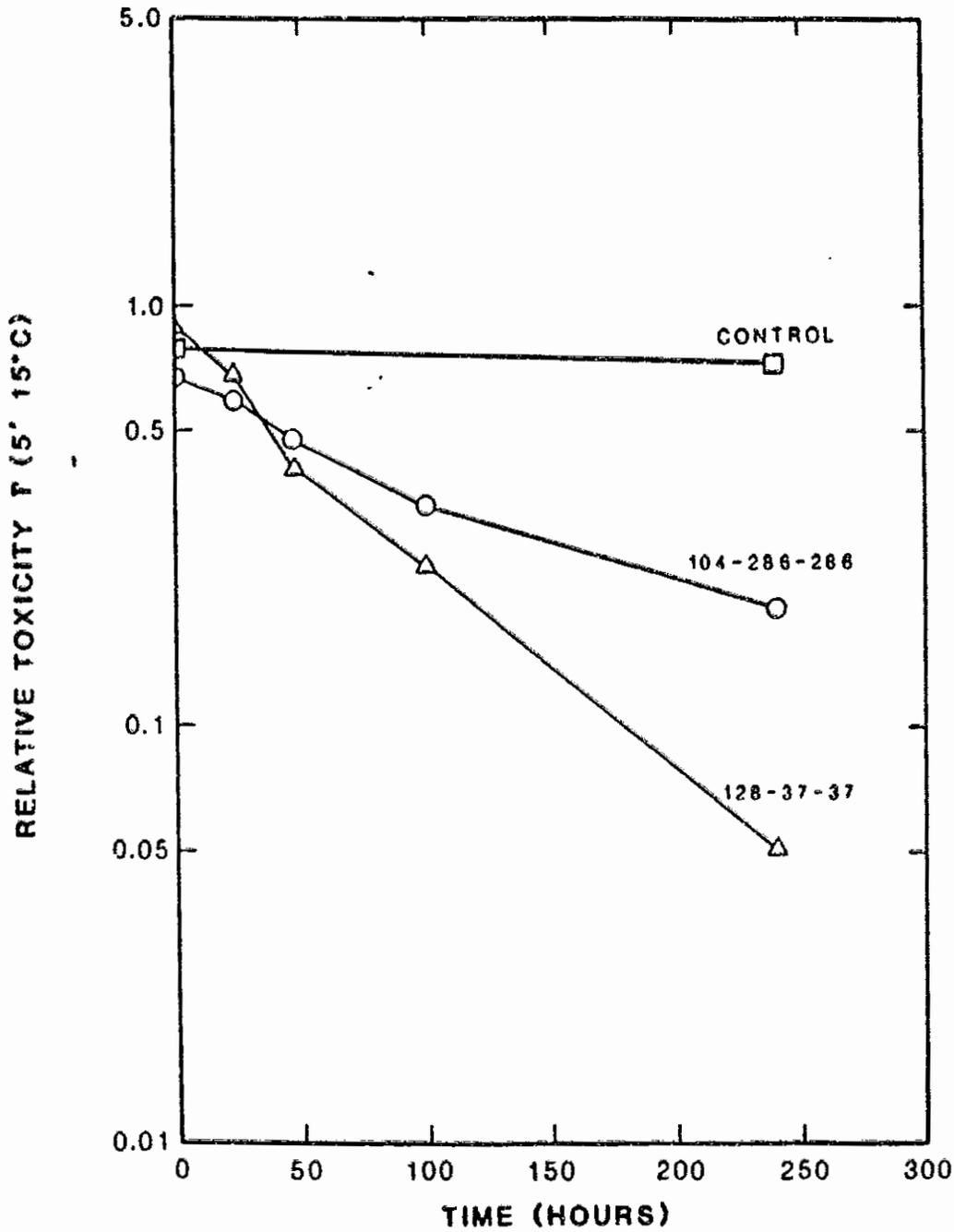

NUMBERS DENOTE CONCENTRATION OF N-P_2O_5-K_2O IN ppm

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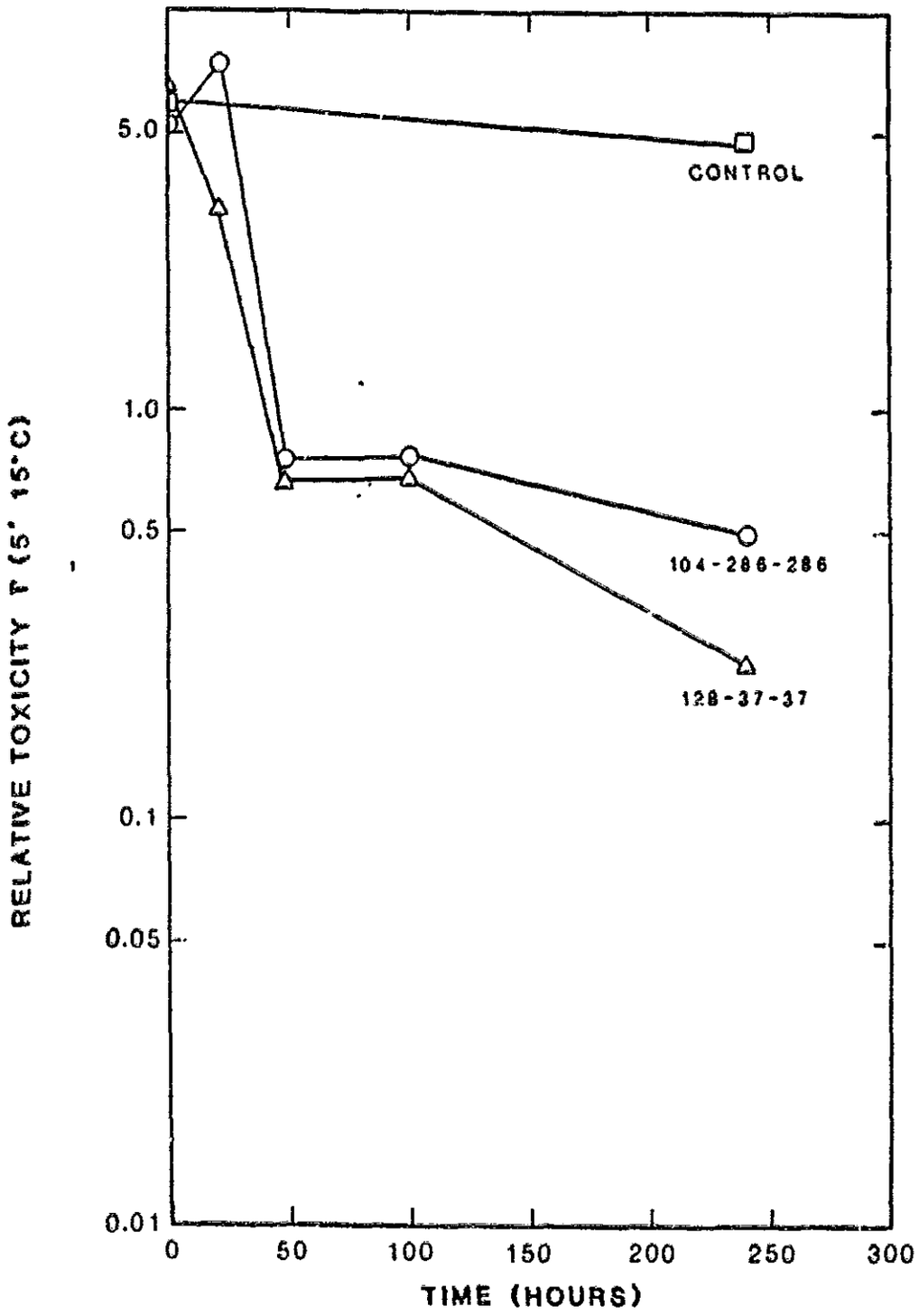
FIGURE 6-1

BIODEGRADATION OF SLUDGE NO. 1 WITH TWO SUPPLEMENTS

FRENCH LIMITED

DRAWN BY	DATE	PROJECT NO
L.M.G.	11-7-86	275-17

007352



NUMBERS DENOTE CONCENTRATION OF $N\text{-}P_2O_5\text{-}K_2O$ IN ppm

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FIGURE 5-2

BIODEGRADATION OF SLUDGE NO. 2 WITH TWO SUPPLEMENTS

FRENCH LIMITED

DRAWN BY	DATE	PROJECT NO
275-17	11-7-86	275-17

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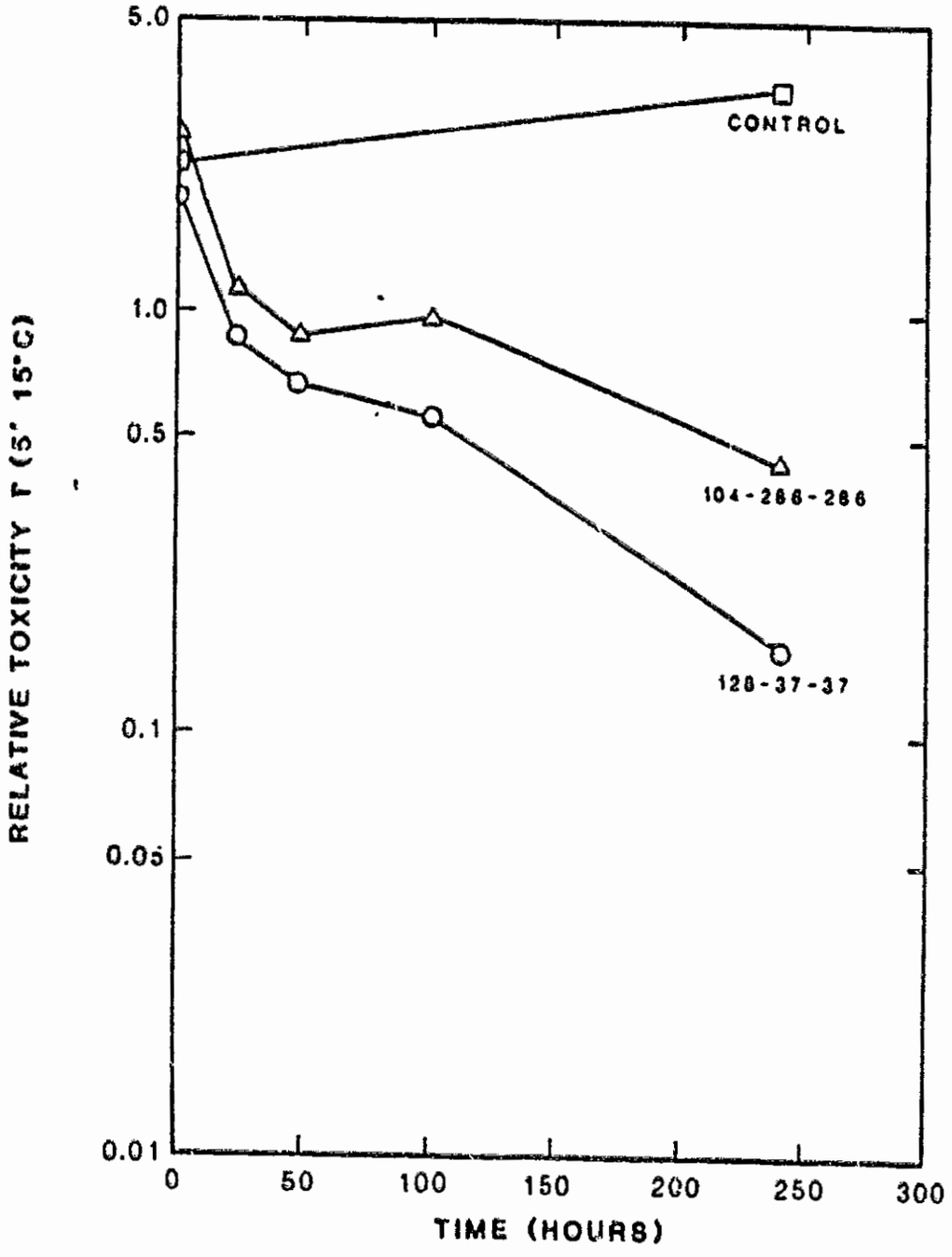

NUMBERS DENOTE CONCENTRATION OF $N\text{-}P_2O_5\text{-}K_2O$ IN ppm

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FIGURE 6-3

BIODEGRADATION OF SLUDGE NO. 3 WITH TWO SUPPLEMENTS

FRENCH LIMITED

DRAWN BY	DATE	PROJECT NO
L.M.G.	11-7-86	275-17

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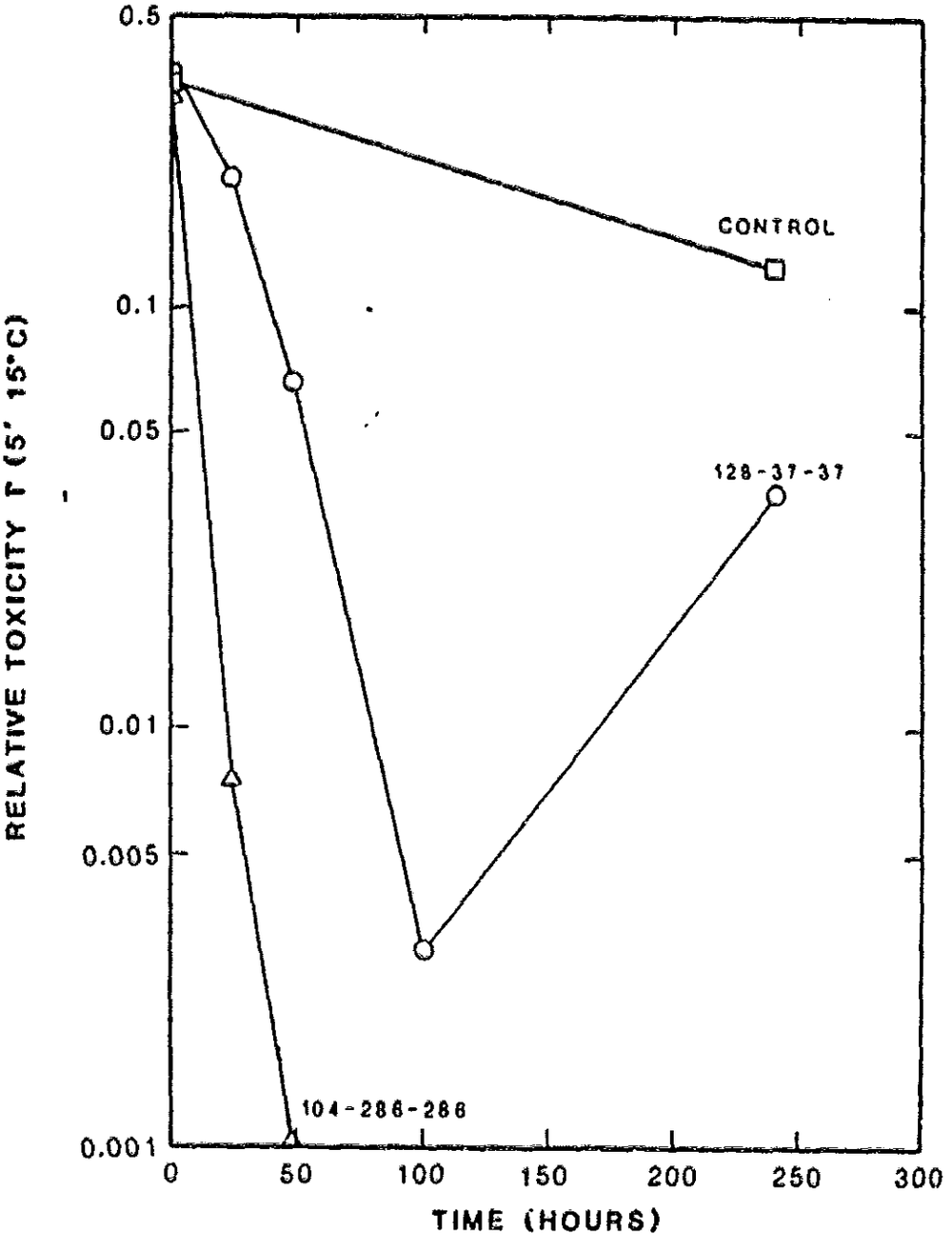

NUMBERS DENOTE CONCENTRATION OF $N\text{-}P_2O_5\text{-}K_2O$ IN ppm.

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FIGURE 5-4

BIODEGRADATION OF SLUDGE NO. 4 WITH TWO SUPPLEMENTS

FRENCH LIMITED

DRAWN BY	DATE	PROJECT NO
L.M.G.	11-7-86	275-17

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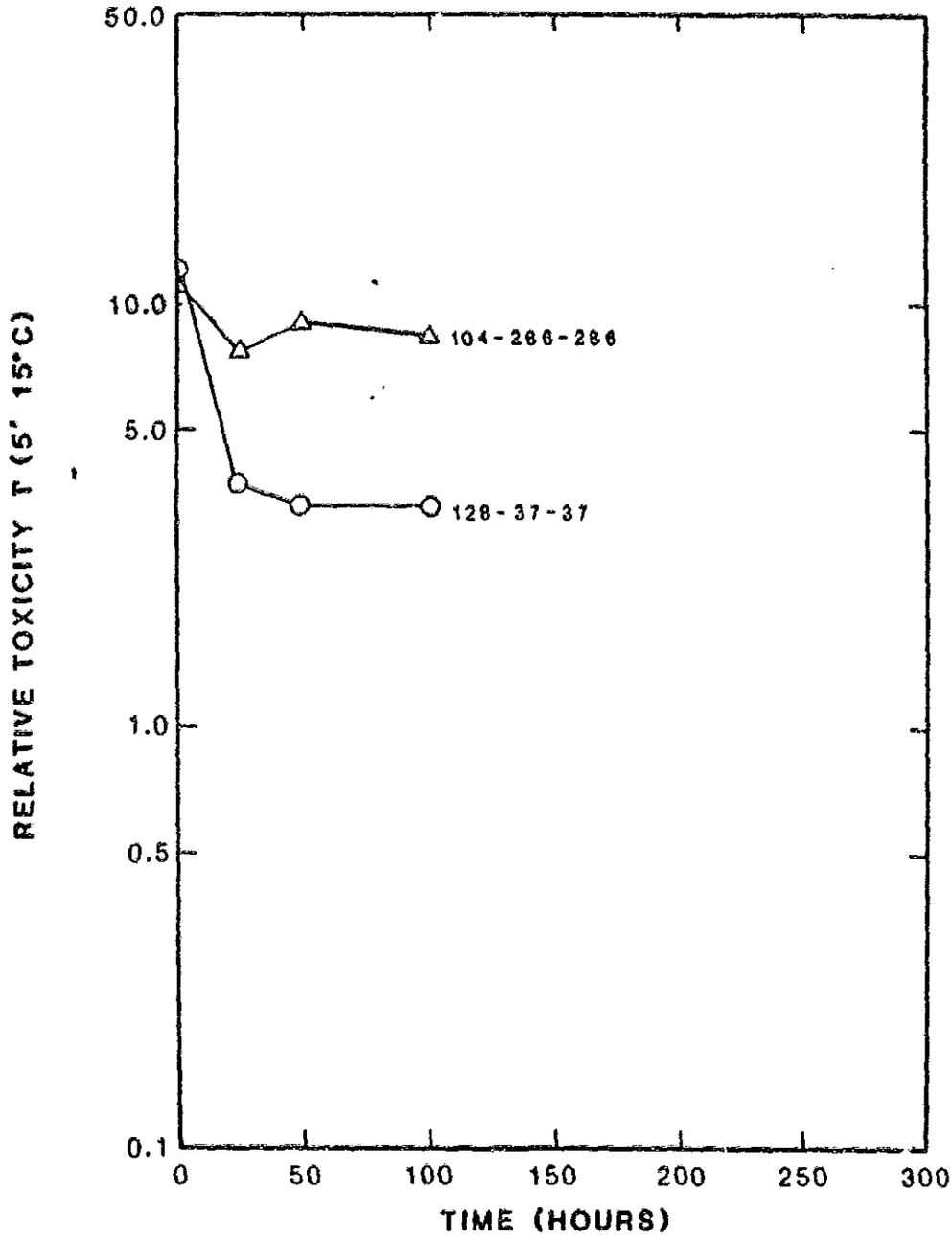

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* NUMBERS DENOTE CONCENTRATION OF $N\text{-}P_2O_5\text{-}K_2O$ IN ppm*

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FIGURE 5-6
BIODEGRADATION OF SUPERNATANT FROM SLUDGE NO. 2 WITH TWO SUPPLEMENTS
FRENCH LIMITED

DRAWN BY	DATE	PROJECT NO
L.M.G.	11-7-86	L.M.G.

007356

TABLE 5-2

Experimental Design and Gamma
Values for Liquid-Liquid Biodegradation of
Sludges with Preliminary Supplements

Sludge	% Loading Capacity	Treatment/100 mls	ppm Nutrients N	P_2O_5	K_2O	Values with Time (hrs)[a] 0	24	48	100	240
1	0.125	Untreated	0	0	0	0.78[b]	NA	NA	NA	0.73
1	0.125	91 mg 14-4-4	128	37	37	0.67	0.59	0.48	0.33	0.19
1	0.125	260 mg 4-11-11	104	286	286	0.89	0.68	0.41	0.24	0.05
2	0.125	Untreated	0	0	0	5.4[b]	NA	NA	NA	4.84
2	0.125	91 mg 14-4-4	128	37	37	5.2	7.4	0.75	0.77	0.50
2	0.125	260 mg 4-11-11	104	286	286	5.6	3.2	0.66	0.68	0.24
3	0.125	Untreated	0	0	0	2.25[b]	NA	NA	NA	3.48
3	0.125	91 mg 14-4-4	128	37	37	1.88	0.86	0.67	0.56	0.16
3	0.125	260 mg 4-11-11	104	286	286	2.61	1.12	0.87	0.96	0.44
4	0.125	Untreated	0	0	0	0.346[b]	NA	NA	NA	1.28
4	0.125	91 mg 14-4-4	128	37	37	0.367	0.201	0.065	0.003	0.036
4	0.125	260 mg 4-11-11	104	286	286	0.324	0.075	0.0	0.0	0.0
Sludge Supernatant										
2	0.125	91 mg 14-4-4	128	37	37	12.03	3.73	3.33	3.33	NA
2	0.125	260 mg 4-11-11	104	286	286	11.27	7.57	9.02	8.40	NA

a. Illustrated in Figures 5-1, 5-2, 5-3, 5-4, and 5-5.
b. Derived

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were added to the sixth flask as a control. Three treatment flasks also received one of the following amounts and grade of fertilizer; 180.4 mg of 19.4-19.4-0; 1094 mg of 32-0-0; or 109.4 mg of 32-0-0. The six sealed flasks for each sludge mixture were then incubated at room temperature with shaking at 45 RPM. At times 0, 24, 48, 72, 120 and 240 hours after mixing, 5 ml was removed from each flask and tested for toxicity.

The decrease in toxicity with respect to time for sludge samples #1, #2, and #3 in the presence of the various fertilizer mixtures are given in Figures 5-6, 5-7, and 5-8 respectively. These curves were plotted from the test results data which is also presented in tabular form on Table 5-3. No change was observed in toxicity in the absence of fertilizer; indicating that loss of toxicity is not due to physical loss of the toxicants. For sludge material #1, #2 and #3 no degradation was observed for the high concentration of 32-0-0 plus 12-12-12 and no effect was observed for the low concentration of 32-0-0 with sludge sample #2. Sludge #3 was unchanged by addition of 19.4-19.4-0 plus 12-12-12. All remaining fertilizer additions promoted degradation.

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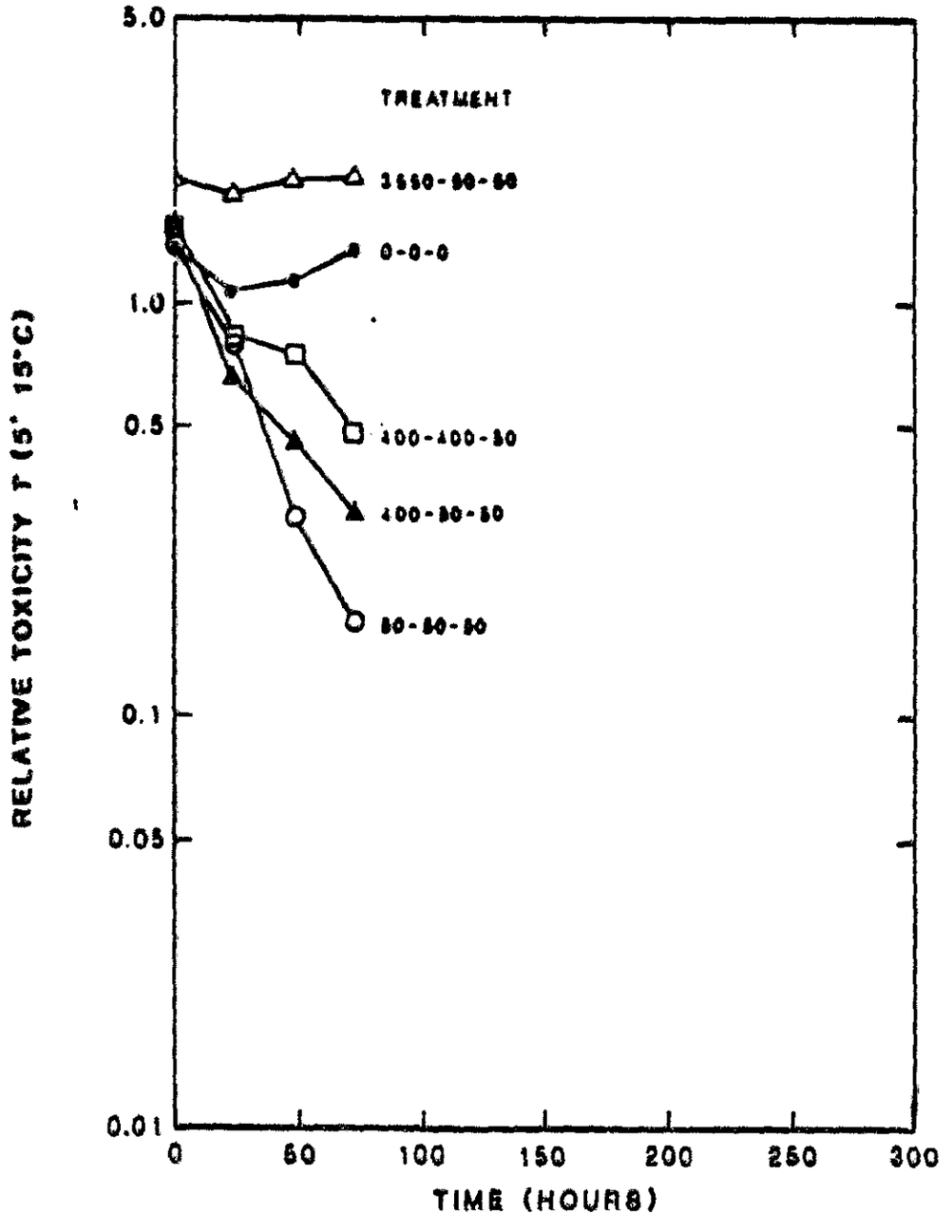

NUMBERS DENOTE CONCENTRATION OF $N\text{-}P_2O_5\text{-}K_2O$ IN ppm

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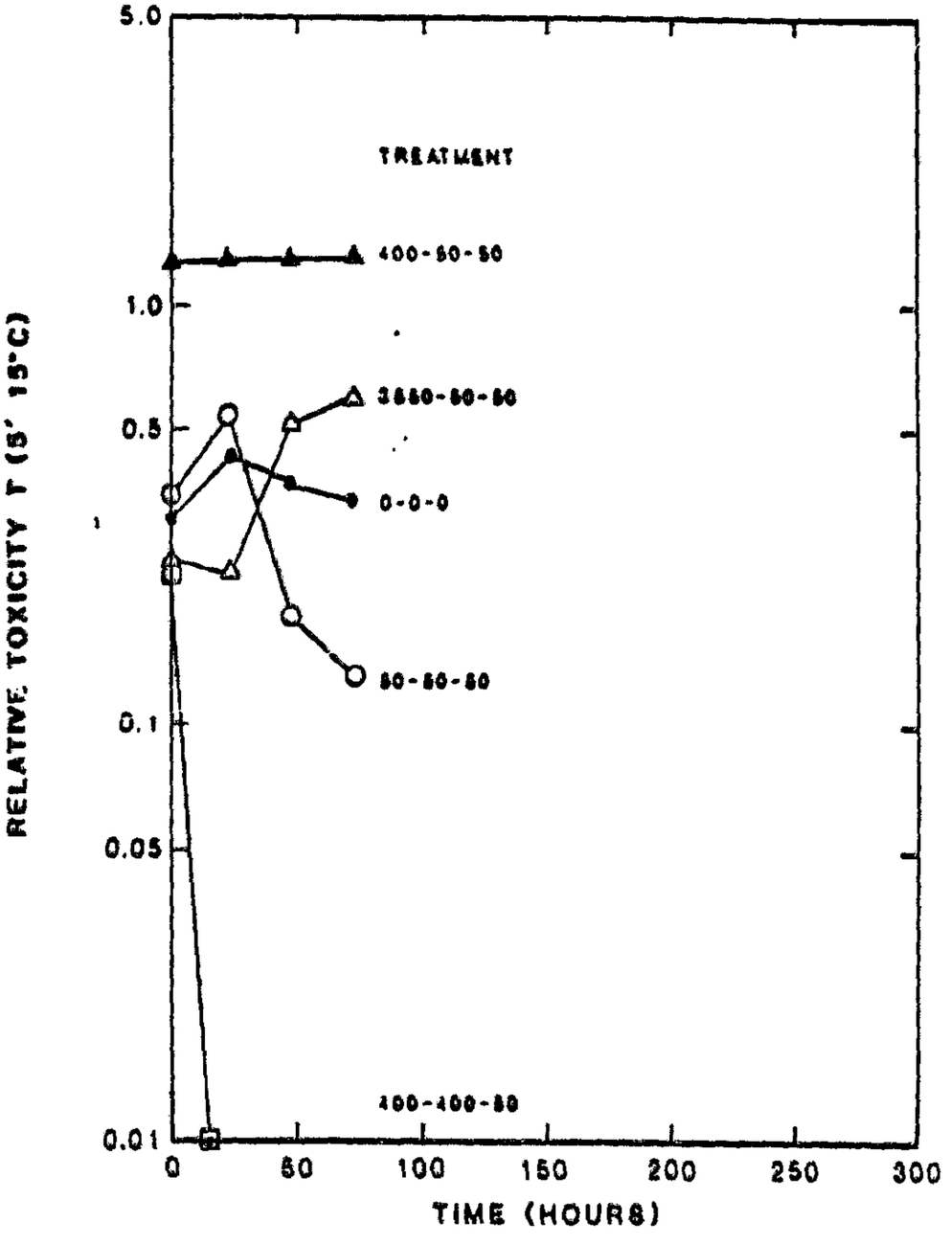
FIGURE 6-8
BIODEGRADATION
OF SLUDGE NO. 1
WITH FOUR SUPPLEMENTS
FRENCH LIMITED

DRAWN BY	DATE	PROJECT NO
L.M.G.	11-7-88	276-17

007359



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NUMBERS DENOTE CONCENTRATION OF $N\text{-}P_2O_5\text{-}K_2O$ IN ppm

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FIGURE 8-7
BIODEGRADATION OF SLUDGE NO. 2 WITH FOUR SUPPLEMENTS
FRENCH LIMITED

DRAWN BY	DATE	PROJECT NO.
L.M.G.	11-7-88	275-17

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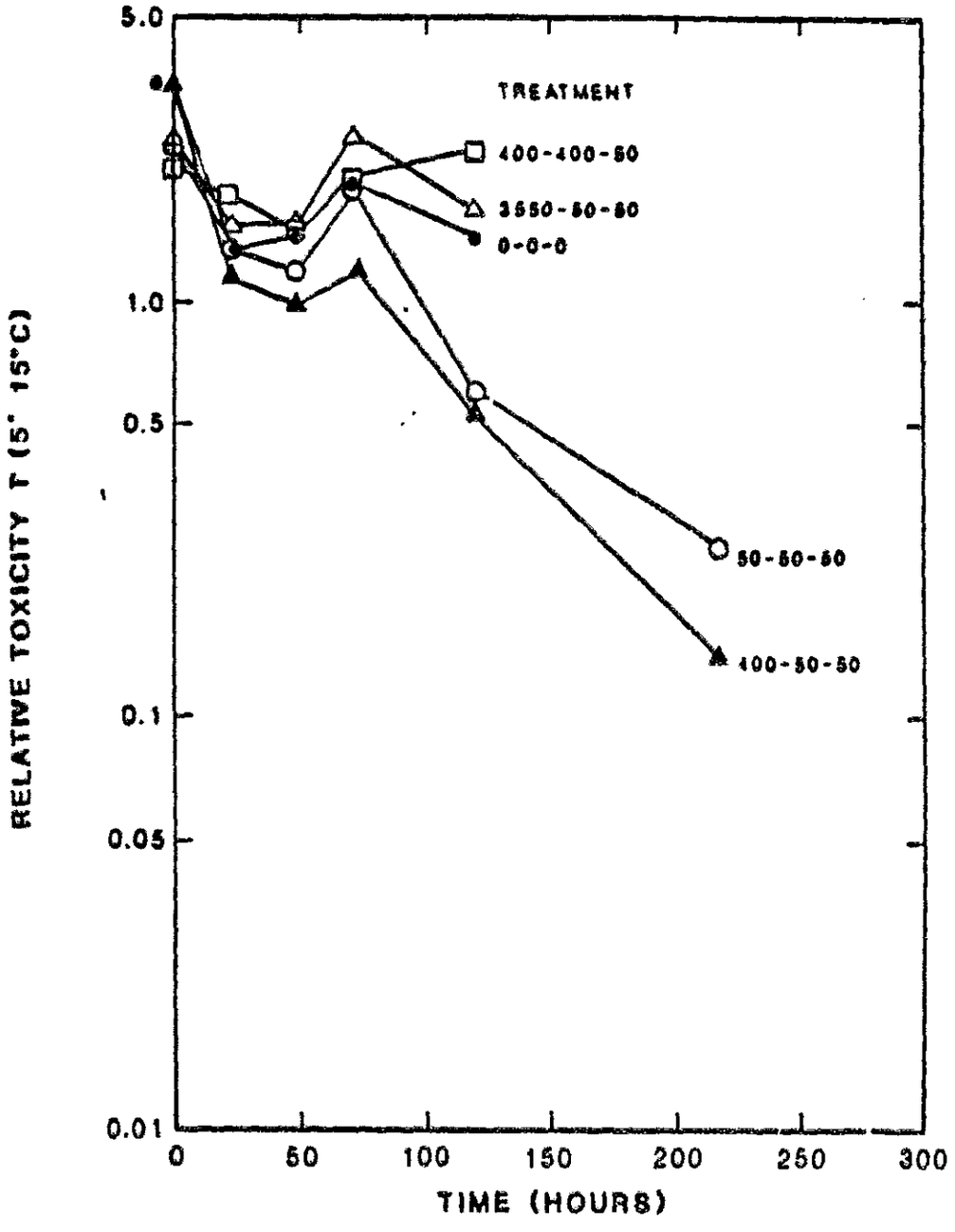

* NUMBERS DENOTE CONCENTRATION OF $N\text{-}P_2O_5\text{-}K_2O$ IN ppm*

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FIGURE 6-8
BIODEGRADATION OF SLUDGE NO. 3 WITH FOUR SUPPLEMENTS
FRENCH LIMITED

DRAWN BY	DATE	PROJECT NO
L.M.G.	11-7-86	275-17

007361

TABLE 5-3
Experimental Design and Gamma Values for Biodegradation of Sludges
Amended with Specific Supplements

Sludge	% Loading Capacity	Treatment/100 mls	ppm Nutrients N	P2O5	K2O	Gamma Values with Time (hrs)a 0	24	48	72	120	216
1	0.125	Control	0	0	0	1.40	1.07	1.13	1.33	NA	NA
		41 mg 12-12-12	50	50	50	1.40	0.80	0.30	0.17	NA	NA
		41 mg 12-12-12; 109 mg 32-0-0	400	50	50	1.59	0.66	0.46	0.31	NA	NA
		41 mg 12-12-12; 1090 mg 32-0-0	3550	50	50	2.01	1.86	2.00	2.07	NA	NA
		41 mg 12-12-12; 182 mg 19.4-19.4-0	400	400	50	1.55	0.83	0.75	0.48	NA	NA
2	0.125	Control	0	0	0	0.32	0.43	0.37	0.34	NA	NA
		41 mg 12-12-12	50	50	50	0.35	0.54	0.18	0.13	NA	NA
		41 mg 12-12-12; 109 mg 32-0-0	400	50	50	1.27	1.29	1.29	1.30	NA	NA
		41 mg 12-12-12; 1090 mg 32-0-0	3550	50	50	0.25	0.23	0.52	0.55	NA	NA
		41 mg 12-12-12; 182 mg 19.4-19.4-0	400	400	50	0.23	0.002	0.0	0.0	NA	NA
3	0.125	Control	0	0	0	6.98	2.76	2.98	3.90	2.88	NA
		41 mg 12-12-12	50	50	50	5.05	2.74	2.38	3.93	1.21	0.51
		41 mg 12-12-12; 109 mg 32-0-0	400	50	50	6.98	2.30	1.99	2.40	1.07	0.28
		41 mg 12-12-12; 1090 mg 32-0-0	3550	50	50	5.16	3.14	3.19	5.22	3.37	NA
		41 mg 12-12-12; 182 mg 19.4-19.4-0	400	400	50	4.33	3.70	3.06	4.06	4.77	NA

a. Illustrated in Figures 5-6, 5-7, and 5-8

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6.0 DETERMINATION OF INOCULUM SOURCE

Biodegradation studies described in Section 5.0 were based on utilizing soil inoculum as the source of microbes. This was viewed as the practical situation which would be encountered in an actual field biodegradation program. The following experiment was designed to determine whether or not microbes were present in the sludges and whether the nutrients in the soil contribute to the biodegradation process.

6.1 Test Methods - Three (3) g of sludge #3 was mixed with 1200 ml of water and 100 ml of this mixture distributed into ten, 1 liter flasks. No nutrients were added to one flask as a control. To one set of four flasks containing 100 ml of the sludge mixture, 41 mg of 12-12-12 fertilizer was added. Three of these flasks also received one the following amounts and grade of fertilizer; 180.4 mg of 19.4-19.4-0; 1094 mg of 32-0-0 or 109.4 mg of 32-0-0. A second set of five flasks were prepared as above except to these was added 1.56 g of sterile soil #3 (sterlization verified by standard microbial techniques).

Two (2) g of sludge #4 were mixed with 800 ml of water and 100 ml of this mixture placed in four, 1 liter flasks. The control flask received no additives. The second and third flasks received either 260 mg of 4-11-11 fertilizer or 1.56 g of sterile soil #4 and flask four received both sterile soil and fertilizer. The flasks were sealed, then incubated at room temperature with shaking at 45 RPM.

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At times 0, 24, 48, 78, 120 and 240 hours after mixing, 5 ml was removed from each flask and tested for toxicity.

6.2 Test Results and Discussion - The results obtained for sludge #3 and sludge #4 are shown in Figure 6-1 and also shown in tabular form on Table 6-1. The control exhibits a slight decrease in toxicity. Likewise, very little degradation was observed for the 12-12-12 plus 10x 32-0-0 and 12-12-12 plus 19.4-19.4-0 with sludge #3 with or without sterile soil. Addition of 12-12-12 with and without 32-0-0 stimulated degradation in both samples with and without sterile soil to the same extent.

With sludge sample #4, degradation with 4-11-11 alone was equivalent to the initial degradation rate obtained in biodegradation tests described in Section 5.1. The addition of sterile soil with or without 4-11-11 to sludge #4 exhibited smaller but significant degradation. Overall these results indicate that soil inoculation is unnecessary to obtain biodegradation of sludges #3 and #4. Also, although the soil does appear to contribute some factor to the degradation process it can be duplicated by the appropriate fertilizer grade.

007364

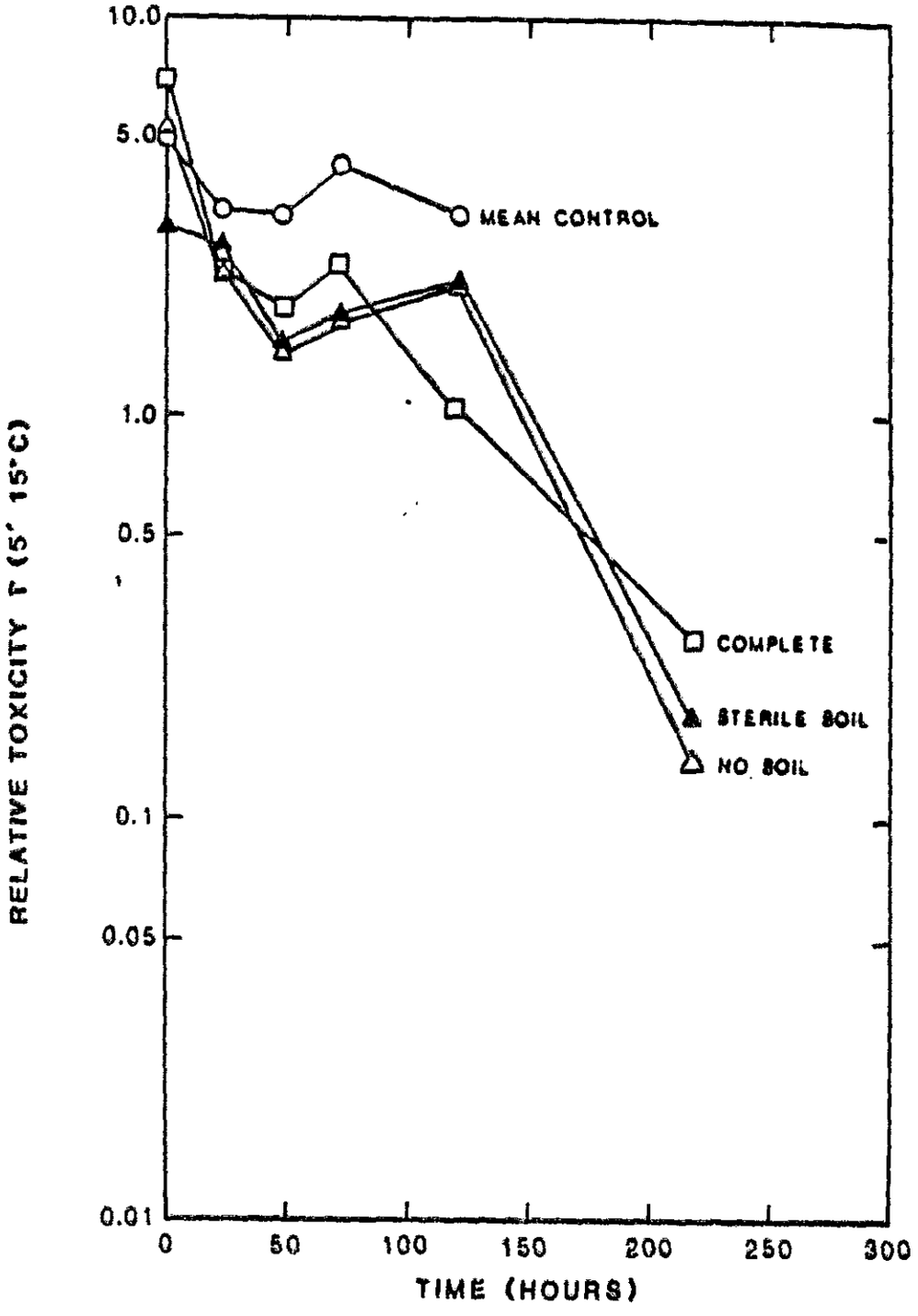

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FIGURE 6-1
INNOCULUM SOURCE FOR BIODEGRADATION OF SLUDGE NO.3 AMENDED WITH 350ppm N
FRENCH LIMITED

DRAWN BY	DATE	PROJECT NO
L.M.G.	11-7-86	275-17

TABLE 6-1

Experimental Design and Gamma Values for Inoculum Source Experiment Using Sludges #3 and #4

Sludge	% Loading Capacity	Soil (g)	Treatment/100 ml	mg Nutrients N	P_2O_5	K_2O	0	Gamma Values with Time (hr)[a] 24	48	72	120	240
3	0.125	1.56	Untreated Control	0	0	0	6.98	2.76	2.98	3.98	2.89	NA
			41 mg 12-12-12	50	56	50	5.85	2.74	2.38	3.93	1.21	0.51
			41 mg 12-12-12; 109 mg 32-0-0	400	50	50	6.98	2.38	1.99	2.48	1.87	0.29
			41 mg 12-12-12; 1090 mg 32-0-0	3550	50	50	5.16	3.14	3.19	5.22	3.37	NA
			41 mg 12-12-12; 182 mg 19.4-19.4-0	400	400	50	4.33	3.70	3.86	4.86	4.77	NA
3	0.25	0	Untreated Control	0	0	0	5.30	4.50	3.71	4.72	1.93	NA
			41 mg 12-12-12	50	50	50	4.60	2.87	1.53	2.33	1.12	0.46
			41 mg 12-12-12; 109 mg 32-0-0	400	50	50	5.30	2.28	1.46	1.73	2.17	0.14
			41 mg 12-12-12; 1090 mg 32-0-0	3550	50	50	7.52	2.55	2.85	2.83	2.27	NA
			41 mg 12-12-12; 182 mg 19.4-19.4-0	400	400	50	5.89	3.90	4.23	3.81	2.36	NA
3	0.25	1.56 (sterile)	Untreated Control	0	0	0	3.0	2.77	2.86	9.68	4.87	NA
			41 mg 12-12-12	50	50	50	2.95	1.55	2.24	2.16	1.17	0.52
			41 mg 12-12-12; 109 mg 32-0-0	400	50	50	3.88	2.71	1.52	1.81	2.22	0.18
			41 mg 12-12-12; 1090 mg 32-0-0	3550	50	50	4.96	2.33	2.51	2.55	2.18	NA
			41 mg 12-12-12; 182 mg 19.4-19.4-0	400	400	50	6.70	2.87	1.96	2.43	2.69	NA
4	0.25	1.56	268 mg 4-11-11	184	206	206	1.96	0.44	0.25	0.38	NA	NA
	0.25	1.56 (sterile)	268 mg 4-11-11				1.39	0.27	0.18	0.0	NA	NA
	0.25	0	268 mg 4-11-11				2.38	0.29	0.19	0.0	NA	NA
	0.25	0	0	0	0	0	1.68	1.74	1.38	1.33	NA	NA

a. Illustrated in Figures 6-1.

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7.0 SEMI-SOLID BIODEGRADATION OF CONTAMINATED SOILS

7.1 Test Methods - Four hundred grams of contaminated soil from each location were placed in each of three reaction flasks. The pH of contaminated soil #3 was adjusted with 45 mg calcium hydroxide/ 100 g of soil. One of each set served as an untreated control while the remaining two received 41 mg of 12-12-12 / 100 g of soil. One of these from each soil type (#1, #2, #3, and #4) also received the following:

Soil #1: 41.5 mg of 0-4-4 / 100 g soil

Soil #2: 71.0 mg of 14-0-0 / 100 g soil

Soil #3: 41.5 mg of 0-24-12 / 100 g soil

Soil #4: 83.0 mg of 6-12-6 / 100 g soil

An additional flask of contaminated soil #1 received 166 mg of 0-4-4 plus 41 mg of 12-12-12 / 100 g soil. All flasks were incubated at room temperature and sampled at 0, 24, 48, and 168 hours. Extraction for Microtox™ assay used 50 g of soil and 400 ml of water as described above except that the extraction was accomplished by blending 3 times in the following sequence; 5 seconds at low speed, 45 seconds at high speed then 3 minutes off for cooling.

7.2 Test Results and Discussion - The degradation plots for the contaminated soil material are shown in Figures 7-1, 7-2, 7-3, and 7-4 for soils #1, #2, #3, and #4 respectively. These curves were plotted from the test results data which is shown in tabular form on Table 7-1.

007367

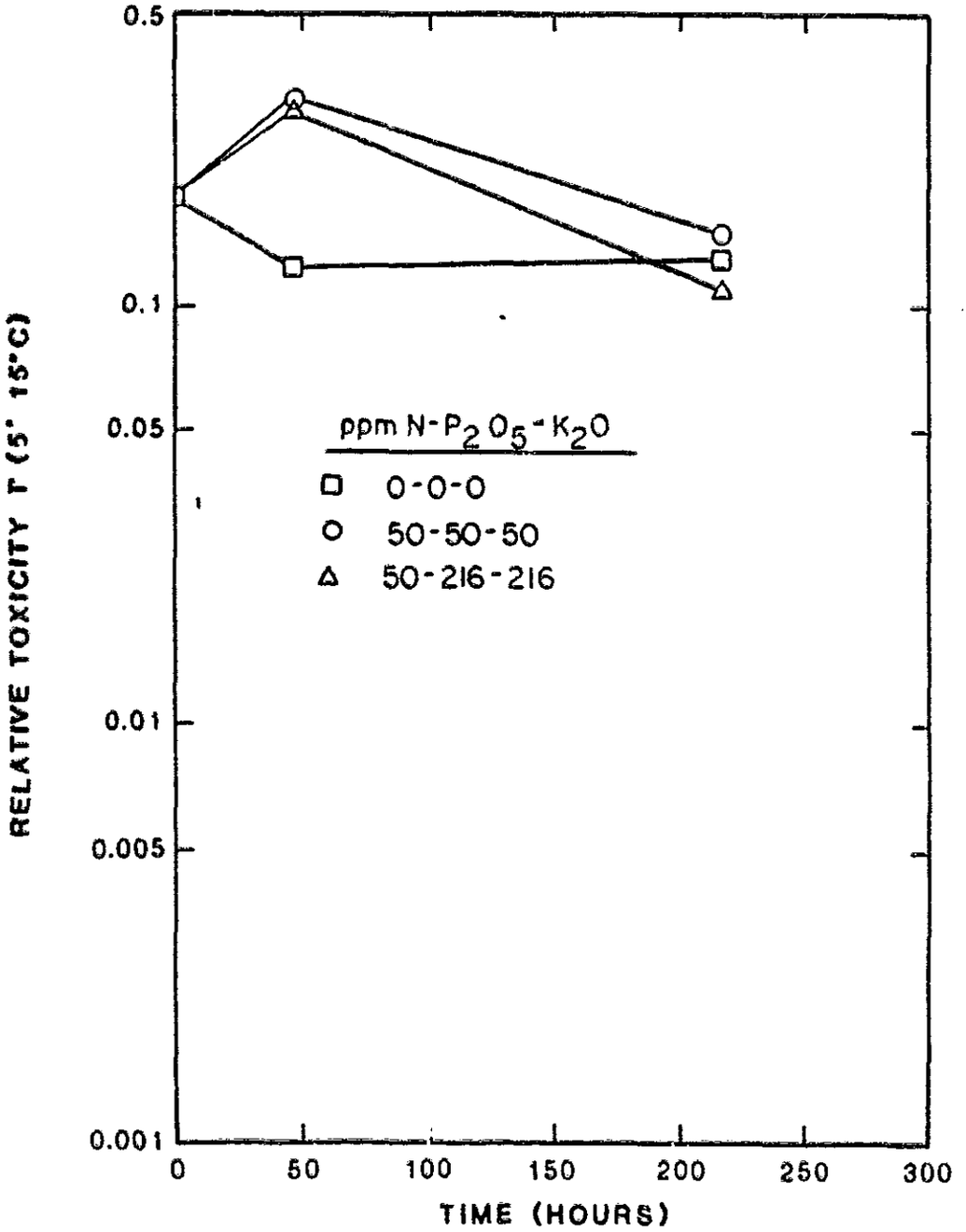

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FIGURE NO.7-1

SEMI SOLID BIODEGRADATION OF CONTAMINANTS IN SOIL NO. 1

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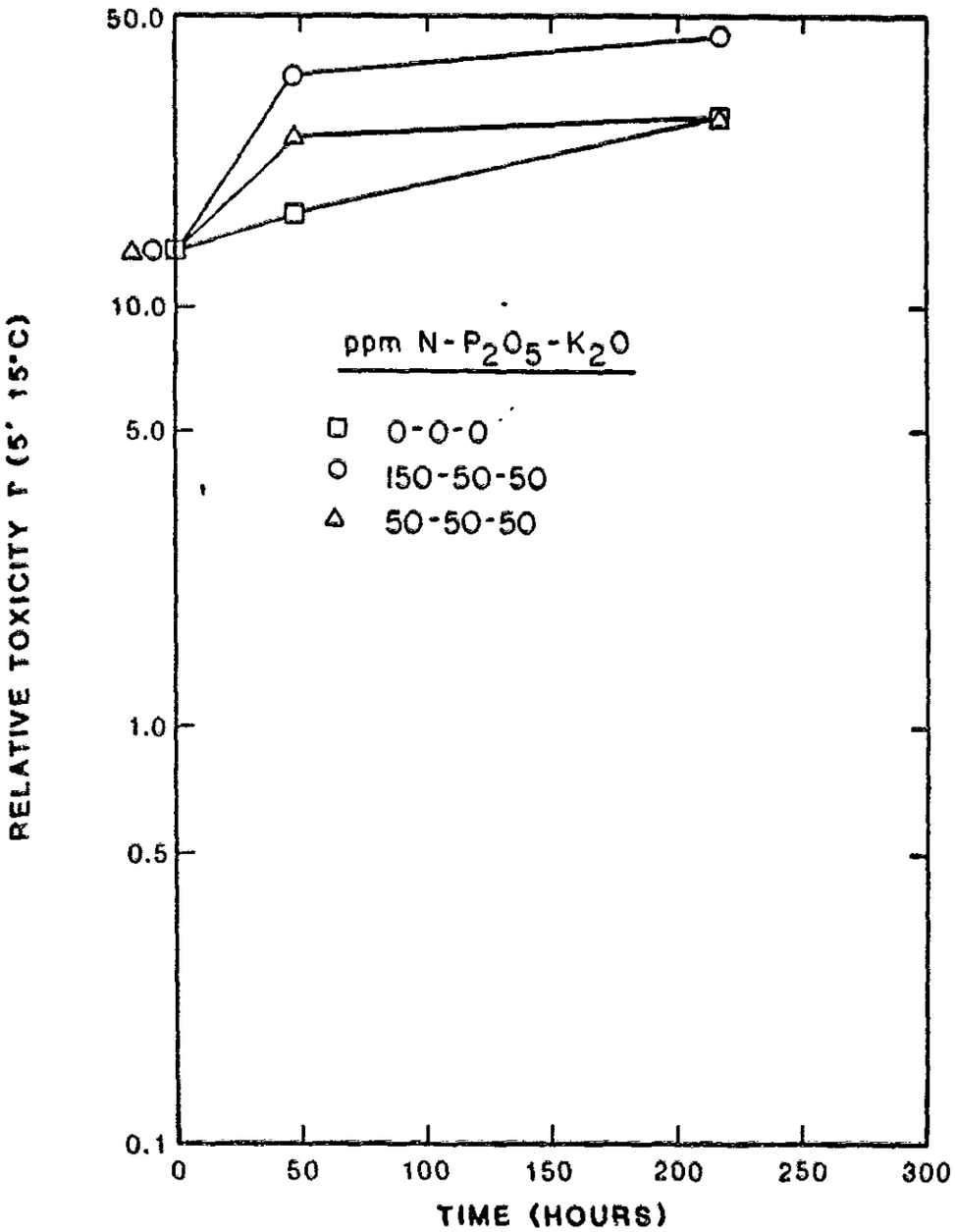

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FIGURE NO.7-2

SEMI SOLID BIODEGRADATION OF CONTAMINANTS IN SOIL NO. 2

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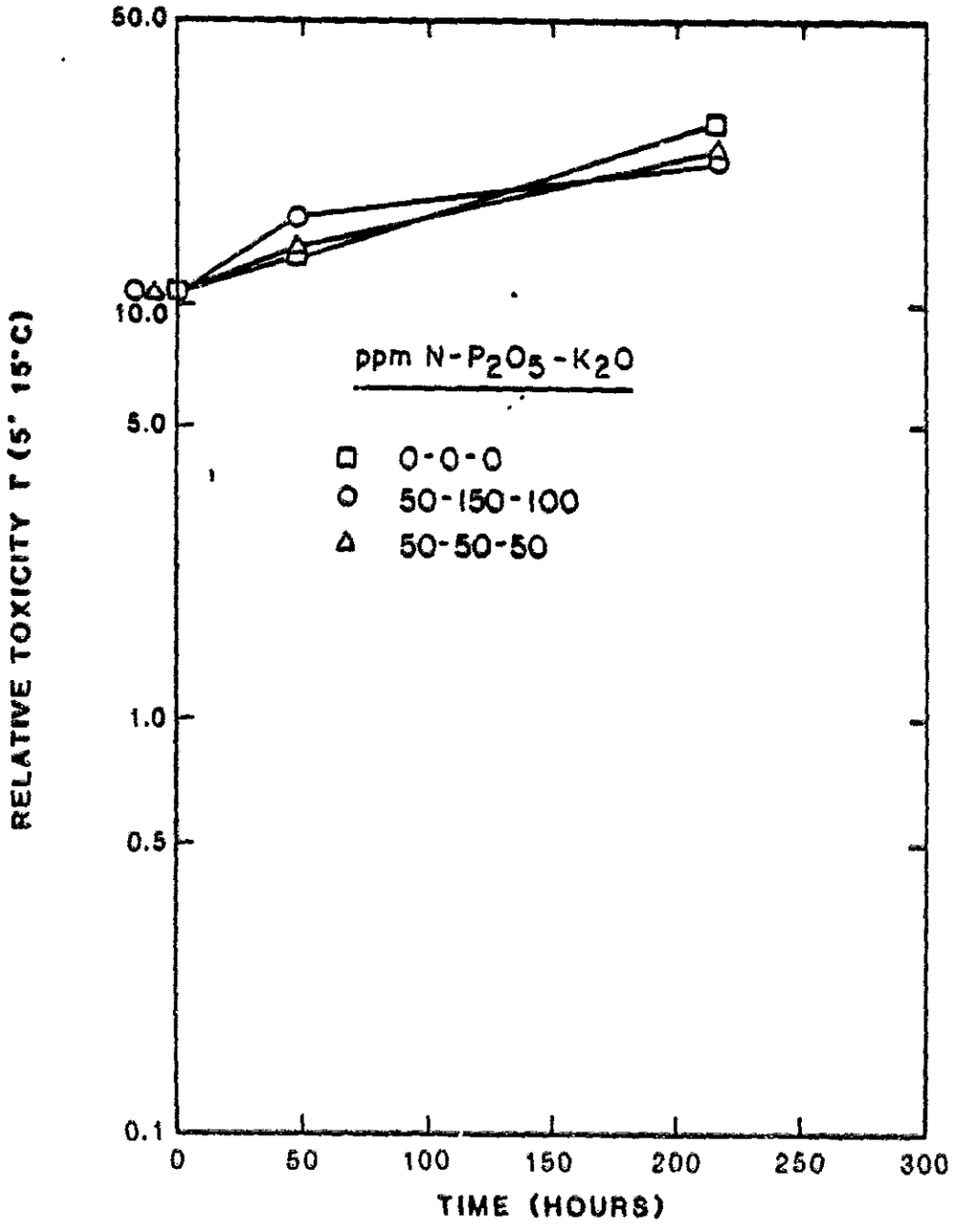

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FIGURE NO. 7-3

SEMI SOLID BIODEGRADATION OF CONTAMINANTS IN SOIL NO. 3

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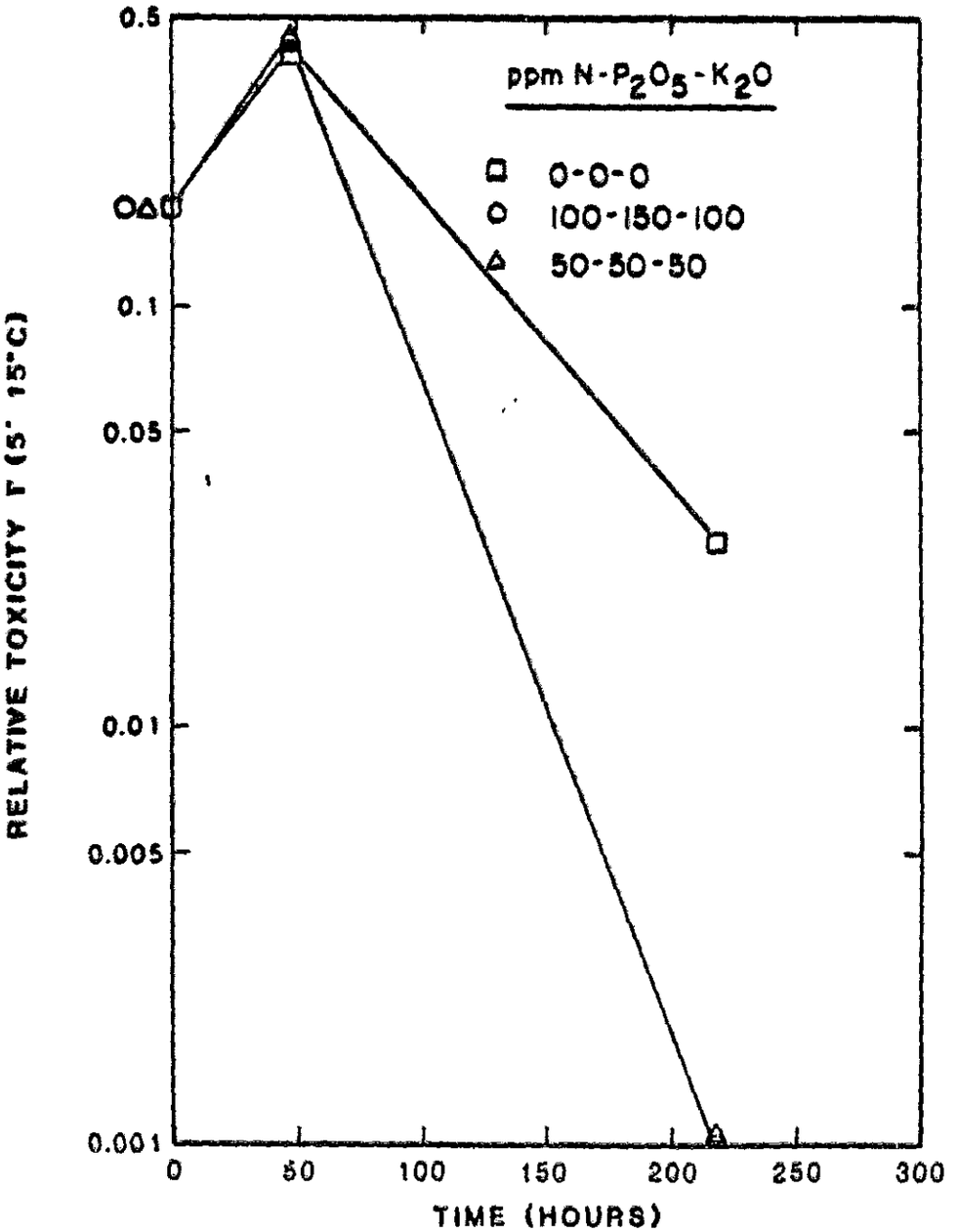

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FIGURE NO.7-4

SEMI SOLID BIODEGRADATION OF CONTAMINANTS IN SOIL NO. 4

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TABLE 7-1

Experimental Design and Gamma Values for Semi-Solid Biodegradation of Contaminated Soils from Four Locations

(hrs)[a] Sludge	% Loading Capacity	Treatment/100 mls	ppm Nutrients N	P_2O_5	K_2O	Gamma Values with Time 0	48	168
1	100	Untreated	0	0	0	0.185	0.124	0.13
1	100	162 mg 12-12-12	50	50	50	0.185	0.293	0.11
1	100	162 mg 12-12-12, 160 mg 0-4-4	50	67	67	0.185	0.307	0.15
1	100	162 mg 12-12-12, 664 mg 0-4-4	50	216	216	0.185	0.300	0.28
2	100	Untreated	0	0	0	13.698	16.877	29.81
2	100	162 mg 12-12-12	50	50	50	13.698	25.65	29.24
2	100	162 mg 12-12-12, 284 mg 14-0-0	150	50	50	13.698	35.95	45.20
3	100	Untreated	0	0	0	1.075	1.342	2.81
3	100	162 mg 12-12-12	50	50	50	1.075	1.356	2.48
3	100	162 mg 12-12-12, 166 mg 0-24-12	50	150	100	1.075	1.659	2.32
4	100	Untreated	0	0	0	0.178	0.411	0.028
4	100	162 mg 12-12-12	50	50	50	0.178	0.454	0.0
4	100	162 mg 12-12-12, 332 mg 6-12-6	100	150	100	0.178	0.444	0.0

a. Illustrated in Figures 7-1, 7-2, 7-3, and 7-4.

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8.0 BIODEGRADATION VERIFICATION WITH CONTAMINANT ANALYSIS

This experiment was designed to confirm the nutrient stimulated biodegradation measured by the Microtox TM method in previous experiments, by repeating them and performing a full priority pollutant analysis on the contaminant material before and after degradation.

8.1 Test and Analysis Methods - Sludge material for this retest was collected using the method described in Section 3.0, from contaminant material procurement locations #3 and #4 at the east and west ends of the lagoon respectively, as shown on Figure 8-1. Samples of this sludge material were collected in the field using standard French Limited sludge sampling procedures (see the June, 1986 Remedial Investigation Report) for priority pollutant analysis, including volatiles, acid base neutrals pesticides and PCB's.

The toxicity of the contaminant material sludges and soils was measured by the Microtox™ bioassay system after dilution to 0.17 weight/volume and 1.07 weight/volume respectively. For sludges, 10 g was dispersed in 500 mls of water; 1 ml was diluted in 9 ml of water then 0.5 ml was added to 0.5 ml of the reconsituted assay organisms. Soils were treated as above except that 20g was homogenized in 100 ml of water prior to further dilution and assay. The resulting Gamma values from these tests are shown in Table 8-1.

The projected loading capacity was calculated from the EC_{50} values determined in Section 4.0 for contaminant material from Locations #3 and #4. Contaminant sludges and

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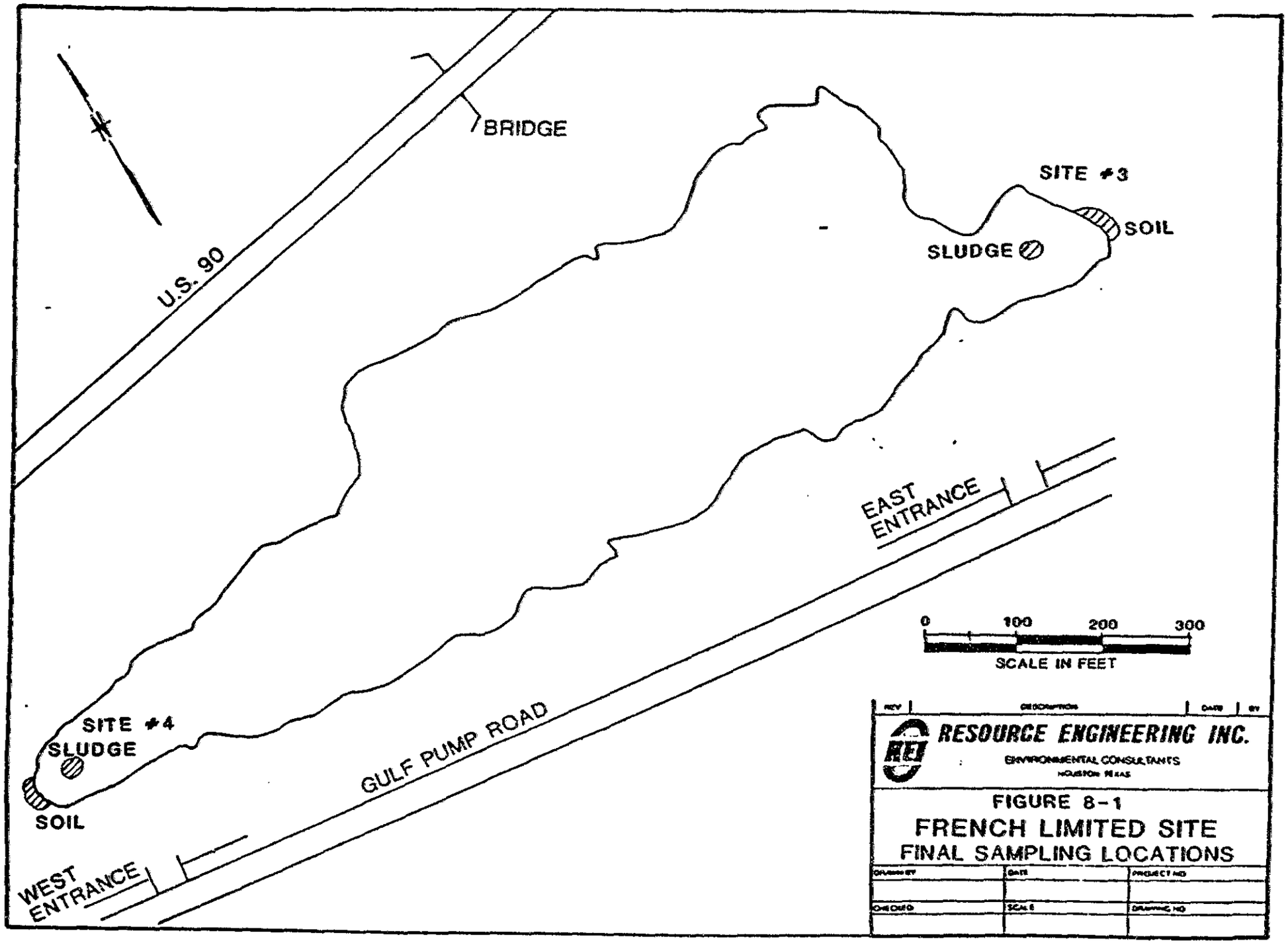

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TABLE 8.1

Summary of Gamma Values and
Physical Loading Capacity for Soil and
Sludge from Locations #3 and #4

	Dilution Factor	Tau EC_{50}	Projected % Loading Capacity	Actual % Loading Capacity	Loading Capacity Factor
Sludge #3	0.001	12.28	0.012%	0.03%	2.5
Soil #3	0.01	0.13	15.00%	20.00%	1.3
Sludge #4	0.001	5.52	0.036%	0.10%	2.8
Soil #4	0.01	0.28	7.00%	20.00%	2.9

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contaminated soils were adjusted to the actual percent loading capacity with water. The actual loading capacity was higher than the calculated values by factors ranging from 1.3 to 2.9. The biodegradation reaction mixture for each contaminant material was incubated in four flasks, each with a final, loaded volume of 500ml. Two flasks from each contaminant material received nutrients and two remained untreated. The experimental design and resulting gamma values are summarized in Table 8.2.

The reaction mixture was incubated and sampled as described in Section 5.0. The biodegradation experiment was terminated when the relative toxicity according to Microtox™ decreased at least one log cycle. The final reaction mixture for each contaminant material, alone, and with nutrients was submitted for a full priority pollutant analysis, similar to the analysis performed on the original sludge samples.

8.2 Test Results and Discussion - Gamma values for the biodegradation of contaminant sludge and soil from Locations #3 and #4 are shown in Tabular form in Table 8-2, and plotted in Graphical form in Figure 8-2 and Figure 8-3 respectively. Soils and sludges unsupplemented with nutrients showed little change in relative toxicity during the 9 day incubation period. Treated sludges and soils exhibited degradation kinetics consistent with the previous biodegradation experiments described in Section 5.0.

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TABLE 8-2

Experimental Design and Gamma Values for Final Biodegradation of Sludge and Soil from Locations #3 and #4

Sludge	% Loading Capacity	Treatment/100 mls	ppm Nutrients N	P_2O_5	K_2O	Rep	Gamma Values with Time (hrs)[a] 0	72	120	216	456
Sludge 3	0.03	Control	0	0	0	A	3.49	NA	2.78	3.70	NA
						B	NA	NA	3.40	4.15	NA
	0.03	91 mg 14-4-4	128	37	37	A	3.42	0.65	0.36	0.28	0.11
						B	NA	0.61	0.30	0.25	0.06
Soil 3	20.0	Control	0	0	0	A	0.35	NA	NA	0.48	NA
						B	NA	NA	NA	0.52	NA
	20.0	182 mg 14-4-4	256	74	74	A	0.37	0.11	0.03	0.07	0.39
						B	NA	0.20	0.12	0.15	0.26
Sludge 4	0.1	Control	0	0	0	A	3.23	NA	3.29	3.90	NA
						B	NA	NA	3.23	3.70	NA
	0.1	260 mg 4-11-11	104	286	286	A	3.58	0.65	0.35	0.07	0.08
						B	NA	0.64	0.26	0.02	0.0
Soil 4	20.0	Control	0	0	0	A	0.46	NA	NA	0.69	NA
						B	NA	NA	NA	0.59	NA
	20.0	520 mg 4-11-11	208	572	572	A	0.51	0.28	0.24	0.14	0.22
						B	NA	0.25	0.20	0.11	0.45

a. Illustrated in Figures 8-2 and 8-3.

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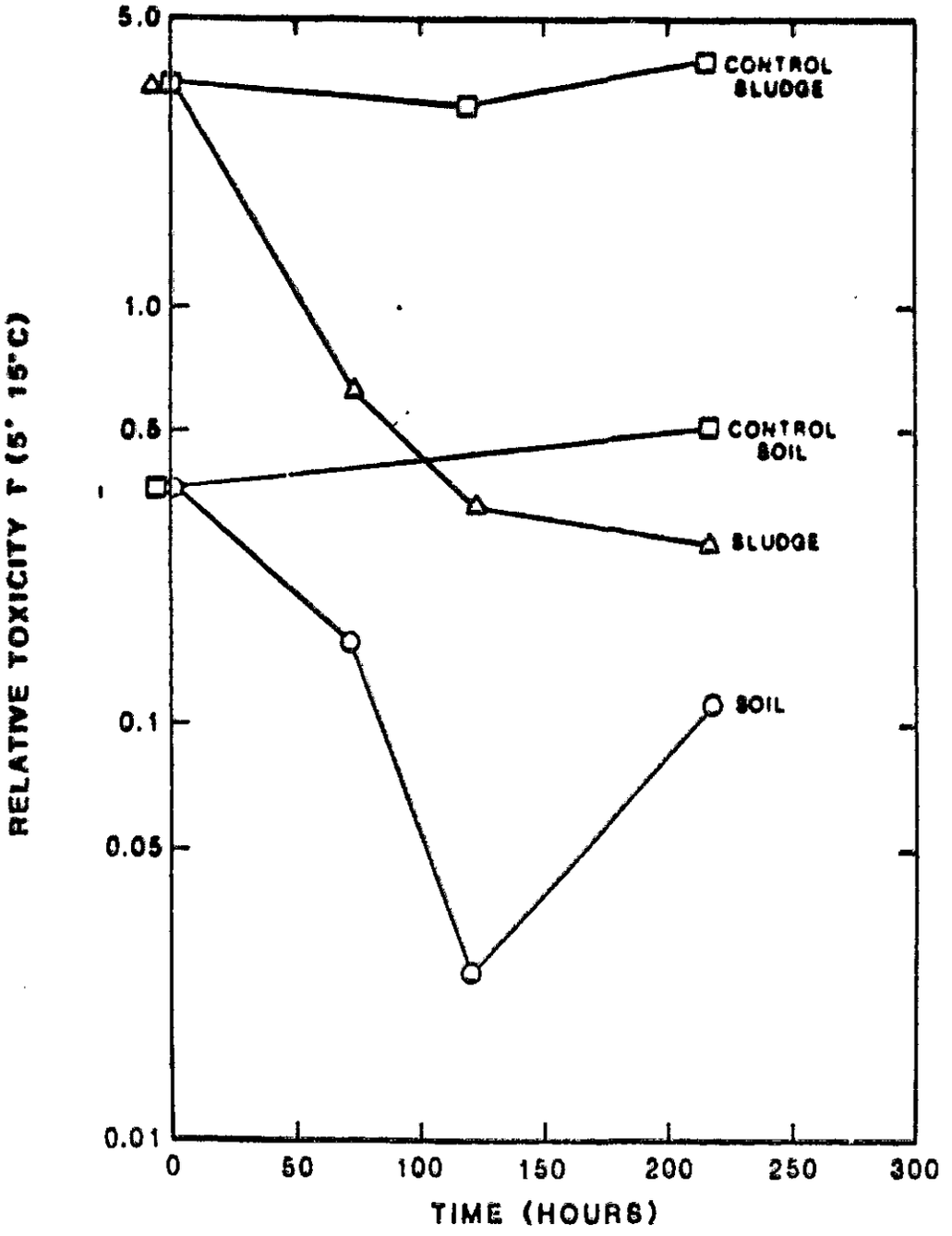

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FIGURE 8-2

BIODEGRADATION OF SLUDGE NO. 3 AND SOIL NO. 3

FRENCH LIMITED

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L.M.G.	11-6-86	275-17

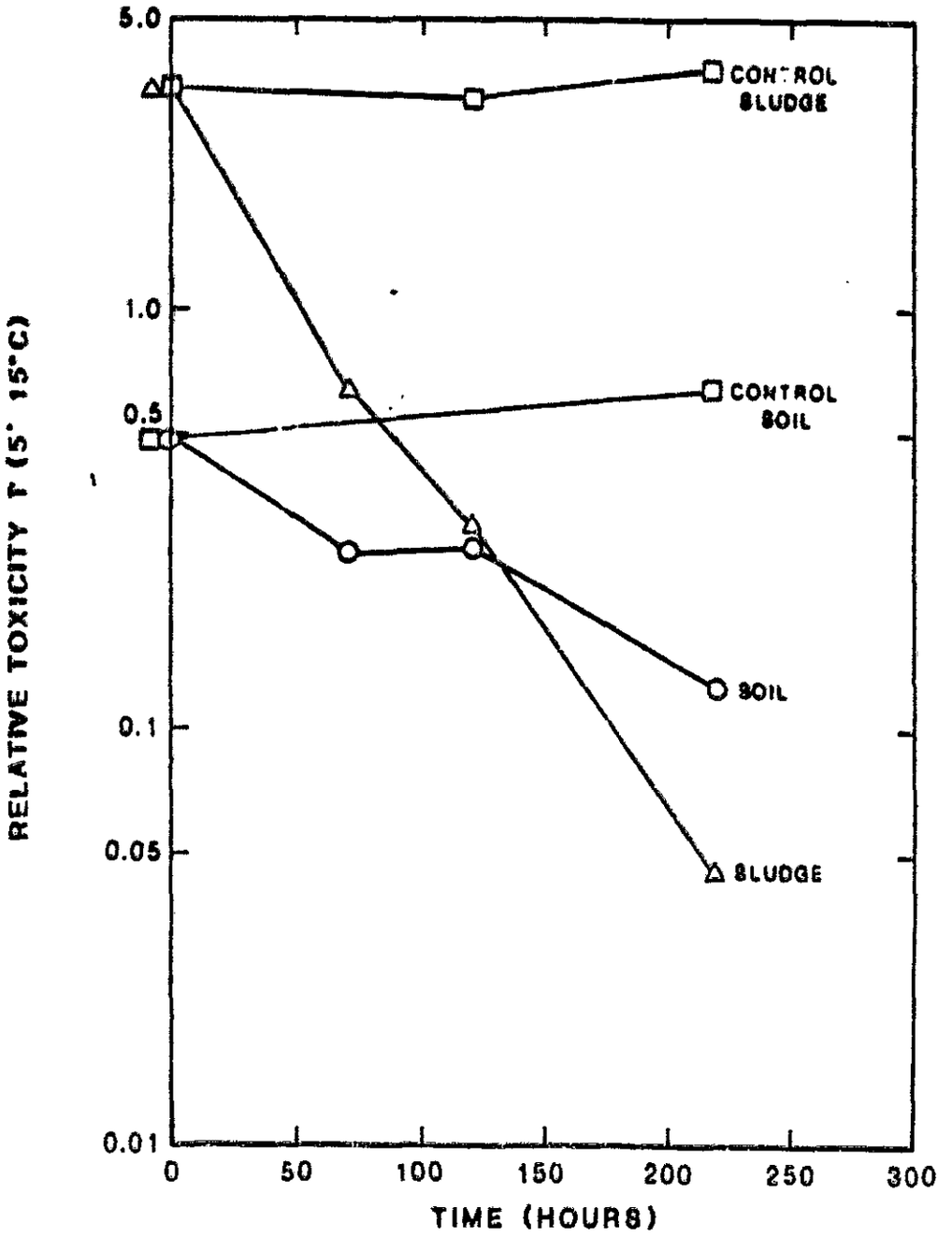

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FIGURE 6-3

BIODEGRADATION OF SLUDGE NO. 4 AND SOIL NO. 4

FRENCH LIMITED

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Sludge #4 exhibited a rapid and constant degradation rate while sludge #3 showed rapid loss in toxicity within 5 days followed by degradation at a much lower rate. Both contaminant soils exhibited lower degradation rates than their corresponding sludges. Contaminant solubility and desorption kinetics may be rate determining factors. After 9 days of decreasing toxicity, both soils exhibited an increased toxicity suggesting that the degradation proceeds via intermediates of varying toxicity.

Gas chromatagraphic analyses for volatile priority pollutants are summarized in Table 8-3. Sludges contain very high levels of volatiles at both locations but none were detected in soils. Residual volatiles following the biodegradation test with supplemental nutrients were significantly lower.

Gas chromatagraphic/Mass spectrographic analyses for base and neutral extractables priority pollutants are summarized in Table 8-4. Again, sludges contain the highest levels of these compounds at both locations, however some were detected in the corresponding soils but at much lower levels. The biodegradation test using nutritional supplementation reduced the concentrations in sludges below detectable limits while significant quantities remained in the tests involving non supplemental mixtures. Biodegradation of the base and neutral extractable compounds in soils was inconsistent with previous observations and Microtox™ data. However the

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TABLE 8-3

GAS CHROMATOGRAPH ANALYSES FOR VOLATILE PRIORITY POLLUTANTS BEFORE AND AFTER BIODEGRADATION OF SLUDGES AND SOILS COLLECTED FROM LOCATIONS #3 AND #4

	Sampling Location #3						Sampling Location #4					
	Sludge			Soil			Sludge			Soil		
	Initial Sample	Final(1) Sample		Initial Sample	Final(1) Sample		Initial Sample	Final(1) Sample		Initial Sample	Final(2) Sample	
VOLATILES		With Nutrients	Without Nutrients		With Nutrients	Without Nutrients		With Nutrients	Without Nutrients		With Nutrients	Without Nutrients
	ppb	ug/l	ug/l	ppb	ug/l	ug/l	ppb	ug/l	ug/l	ppb	ug/l	ug/l
COMPOUND												
Acrolein	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acrylonitrile	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloroethylvinyl ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bis(chloromethyl)ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromomethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichlorodifluoromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl chloride	ND	ND	ND	ND	ND	ND	410,000	ND	155	ND	ND	ND
Chloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene chloride	170,000	ND	ND	ND	ND	ND	9,000	ND	ND	16	ND	ND
Trichlorofluoromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	3,000	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	13	ND	ND	ND	178,000	ND	140	20	ND	ND
trans-1,2-Dichloroethene	320,000	ND	65	ND	ND	ND	ND	ND	205	ND	ND	ND
Chloroform	1,540,000	12	680	ND	ND	ND	ND	ND	ND	ND	ND	ND

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Table 8-3 (continued)

1,2-Dichloroethane	2,050,000	41	790	ND	ND	ND	ND	20	260	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	230,000	ND	47	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	ND	ND	88	ND	ND	ND
trans-1,3-Dichloropropene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	650,000	ND	152	ND	ND	ND	ND	ND	33	ND	ND	ND
cis-1,3-Dichloropropene	ND	ND	ND	ND	ND	ND	6,000	ND	12	ND	ND	ND
Benzene	400,000	ND	68	20	ND	ND	ND	ND	70	ND	ND	ND
1,1,2-Trichloroethane	ND	ND	ND	ND	ND	ND	39,000	ND	65	ND	ND	ND
Dibromochloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoform	ND	ND	13	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	ND	ND	26	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	130,000	ND	26	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	500,000	ND	91	ND	ND	ND	ND	ND	160	ND	ND	ND
Chlorobenzene	320,000	ND	ND	ND	ND	ND	6,000	ND	ND	ND	ND	ND
Ethylbenzene	540,000	ND	72	ND	ND	ND	ND	ND	225	ND	ND	ND
ND = Not Detected Below:	100.0 ug/gm	10.0 ug/l	10.0 ug/l	10.0 ug/kg	10.0 ug/l	10.0 ug/l	10.0 ug/gm	10.0 ug/l	10.0 ug/l	10.0 ug/kg	10.0 ug/l	10.0 ug/l

1. 9 day incubation period.
2. 19 day incubation period.

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TABLE 8-4

GAS CHROMATOGRAPH/MASS SPECTROGRAPH ANALYSES FOR BASE/NEUTRAL EXTRACTABLES PRIORITY POLLUTANTS BEFORE AND AFTER BIODEGRADATION OF SLUDGES AND SOILS COLLECTED FROM LOCATIONS #3 AND #4

	Sampling Location #3						Sampling Location #4					
	Sludge			Soil			Sludge			Soil		
	Initial Sample	Final(1) Sample		Initial Sample	Final(1) Sample		Initial Sample	Final(1) Sample		Initial Sample	Final(2) Sample	
BASE NEUTRALS		With Nutrients	Without Nutrients		With Nutrients	Without Nutrients		With Nutrients	Without Nutrients		With Nutrients	Without Nutrients
	ppb	ug/l	ppb	ppb	ug/l	ppb	ppb	ug/l	ppb	ppb	ug/l	ug/l
COMPOUND												
1,3-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
bix(2-Chloroethyl)ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
bis(2-Chloroisopropyl)ether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitroso-di-N-propylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobutadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2,4-Trichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Isophorone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	2,760,000	ND	420	ND	ND	ND	658,000	ND	710	ND	ND	ND
bis(2-Chloroethoxy)methane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorocyclopentadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloronaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthylene	567,000	ND	ND	ND	ND	ND	110,000	ND	970	3,800	990	ND
Acenaphthene	467,000	ND	200	ND	5,130	ND	60,000	ND	ND	ND	ND	ND
Dimethylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,6-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

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Table 8=4 (continued)

Fluorene	6,490,000	ND	300	ND	ND	ND	156,000	ND	1,850	ND	ND	ND
4-Chlorophenylphenylether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Diphenylhydrazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Diethylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodiphenylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Bromophenylphenylether	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthracene	382,000	ND	ND	ND	621	ND	96,000	ND	3,550	ND	ND	ND
Phenanthrene	2,060,000	ND	620	950	358	ND	295,000	ND	2,720	ND	ND	ND
Di-n-butylphthalate	60,000	ND	ND	ND	ND	ND	17,000	ND	ND	2,200	ND	ND
Fluoranthene	465,000	ND	ND	7,400	1,550	660	57,000	ND	1,100	13,800	352	436
Pyrene	600,000	ND	ND	10,100	2,924	1,050	53,000	ND	990	24,600	1,639	681
Benzidine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Butylbenzylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
bis(2-Ethylhexyl)phthalate	ND	ND	ND	ND	ND	350	ND	ND	ND	12,200	ND	ND
Chrysene	73,000	ND	ND	ND	815	ND	19,000	ND	ND	3,600	262	ND
Benzo(A)anthracene	76,000	ND	ND	ND	316	ND	14,000	ND	ND	ND	ND	ND
3,3'-Dichlorobenzidine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Di-n-octylphthalate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(B)fluoranthene	ND	ND	ND	ND	625	ND	ND	ND	ND	3,400	ND	ND
Benzo(K)fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(A)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	352	ND
Indeno(1,2,3-C,D)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo(A,H)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(G,H,I)perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
N-Nitrosodimethylamine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ND = Not Detected Below:	50.0 ug/gm	100 ug/l	200 ug/kg	1.0 ug/gm	300 ug/l	300 ug/kg	10.0 ug/gm	50 ug/l	300 ug/kg	2.0 ug/gm	100 ug/l	100 ug/l

1. 9 day incubation period.
2. 19 day incubation period.

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analysis does confirm that degradation occurred. In this case, lower residual contaminant levels were found in the tests without supplemental nutrients.

Gas chromatagrapic/mass spectragraphic analyses for acid extractables and pesticides are shown in Table 8-5. Phenol was the only acid extractable found and it was present only in sludges from both locations. Biodegradation reduced the level of phenol below detectable limits in all cases. The sole pesticide detected was PCB-1242, present in significant concentrations in sludge and soil from both locations. No PCB-1242, was detected following degradation of the sludge with or without nutritional supplements. However, measureable quantities remained following biodegradation of the soil contaminants at both locations.

Table 8-6 presents the Quantitive Metals Analysis before and after biodegradation.

The analytical chemical GC/MS results supports the Microtox bioassay findings in the following conclusions.

1. Sludges are more toxic than soils and therefore require lower loading rates
2. Biodegradation of the sludges is more rapid and complete than biodegradation of the contaminants contained in the soils.

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TABLE 8-5

GAS CHROMATOGRAPH/MASS SPECTROGRAPH ANALYSES FOR
ACID EXTRACTABLES/PESTICIDE EXTRACTABLES PRIORITY
POLLUTANTS BEFORE AND AFTER BIODEGRADATION OF SLUDGES AND
SOILS COLLECTED FROM LOCATIONS #3 AND #4

	Sampling Location #3						Sampling Location #4					
	Sludge			Soil			Sludge			Soil		
	Initial Sample	Final(1) Sample		Initial Sample	Final(1) Sample		Initial Sample	Final(1) Sample		Initial Sample	Final(2) Sample	
ACID EXTRACTABLES		With Nutrients	Without Nutrients		With Nutrients	Without Nutrients		With Nutrients	Without Nutrients		With Nutrients	Without Nutrients
	ppb	ug/l	ppb	ppb	ug/l	ppb	ppb	ug/l	ppb	ppb	ug/l	ug/l
COMPOUND												
2-Chlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	82,700	ND	ND	ND	ND	ND	68,000	ND	ND	ND	ND	ND
2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4,6-Trichlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
p-Chloro-o-cresol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,6-Dinitro-o-cresol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pentachlorophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Nitrophenol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ND = Not Detected Below:	50.0 ug/gm	100 ug/l	200 ug/kg	1.0 ug/gm	300 ug/l	300 ug/kg	10.0 ug/gm	50 ug/l	300 ug/kg	2.0 ug/gm	100 ug/l	100 ug/l
PESTICIDE EXTRACTABLES												
COMPOUND												
A-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
B-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
D-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
G-BHC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlordane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4'-DDD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

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Table 8-5 (continued)

4,4'-DDE	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4'-DDT	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dieldrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	.5	ND	ND
Endosulfan I	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan II	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan Sulfate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endrin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endrin Aldehyde	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor Epoxide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toxaphene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1016	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1221	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1232	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1242	10,300	ND	ND	9,300	400	1,200	23,100	ND	ND	18,100	1,500	1,200
PCB-1248	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1254	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1260	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
ND = Not Detected Below:	50.0 ug/gm	50.0 ug/l	500 ug/kg	1.0 ug/gm	300 ug/l	300 ug/kg	10.0 ug/gm	50.0 ug/l	300 ug/kg	2.0 ug/gm	100 ug/l	100 ug/l

1. 9 day incubation period.
2. 19 day incubation period.

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TABLE 8-6

QUANTITATIVE METALS ANALYSIS BEFORE AND
AFTER BIODEGRADATION OF SLUDGES AND SOILS
COLLECTED FROM LOCATIONS #3 AND #4

		Sampling Locations #3				Sampling Location #4			
		Sludge		Soil		Sludge		Soil	
	Symb.	Initial mg/kg	Final[1] ug/l	Initial mg/kg	Final[1] ug/l	Initial mg/kg	Final[1] ug/l	Initial mg/kg	Final[2] ug/l
Antimony	Sb	<20	<0.2	<20	<0.2	<20	<0.2	<20	<0.02
Arsenic	As	2.358	0.008	0.809	0.122	0.774	0.023	3.716	0.520
Beryllium	Be	<50	<0.5	<50	<0.5	<50	<0.5	<50	<0.5
Cadmium	Cd	1.42	0.015	0.80	0.019	1.02	0.020	<0.5	0.05
Chromium	Cr	45.2	<0.02	20.0	0.59	86.4	0.15	37.3	4.85
Copper	Cu	165.0	0.3	15.0	0.9	100.0	0.3	28.0	2.7
Lead	Pb	73.0	<0.05	17.0	0.8	42.0	<0.05	31.0	2.3
Mercury	Hg	0.756	0.001	0.148	0.006	0.393	0.005	0.410	0.039
Nickel	Ni	148.6	<0.03	6.3	0.53	17.7	0.048	29.3	2.37
Selenium	Se	1.26	0.04	1.44	0.036	1.12	0.04	<0.10	<0.10
Silver	Ag	<0.83	<0.01	<1.0	<0.01	<0.53	<0.01	<1.0	<0.02
Thallium	Tl	<50	<0.5	<50	<0.5	<50	<0.5	<50	<0.5
Zinc	Zn	177	0.2	37	3.1	248	0.7	72	7.3

1. 9 day incubation period with nutrients.
2. 19 day incubation period with nutrients.

Table 4. Quantitative metals analysis before and after Biodegradation of Sludges and Soils collected from Locations #3 and #4.

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3. Nutritional supplementation promotes rapid, more complete degradation in sludges compared to non-supplemented systems.

4. Biodegradation of soil borne contaminants is much less nutrient dependent than that of sludges. This probably reflects an inate nutrient content of the soils.

5. Additional investigation is required to fully explain the biodegradation results obtained with soil borne contaminants.

9.0 CONCLUSIONS

The following conclusions can be summarized from the laboratory biodegradation evaluation of French Limited contaminants.

- The relative toxicity differed between the various contaminant materials, with sludge supernatant being the most toxic, followed by sludges, and then soil contaminants.

- The relative toxicity of each contaminant material varied between locations in the lagoon. The most toxic sludges and sludge supernatant were found at Location #3. The most toxic soils were found at Location #2.

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- Nutrients required for stimulating biodegradation were location specific, and differed for each location. For example, Location #3 required nitrogen addition whereas Location #4 required phosphate.

- Indigenous organisms capable of degrading sludges were present in the sludge material, probably at the sludge/water interface.

- Contaminants at all locations, and in each material, could be biodegraded by indigenous organisms. The rate of biodegradation was accelerated by the addition of nutrients in the proper ratio.

- Although more toxic than soil material, sludges appear to be degraded more rapidly, and completely than the soils contaminants, within the time frame of the tests.

- The semi-solid degradation system showed little or no degradation within the time frame of the test performed.

- GC/MS analyses confirm that the Microtox™ bioassay toxicity measurement is an effective tool for monitoring the progress of biodegradation activity.

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10.0 RECOMMENDATION

The laboratory biodegradation evaluation on French Limited contaminants indicate that additional large scale pilot investigations are justified, and should be performed under field conditions, to establish an understanding of the technical data base, and the practical mechanics that would be required for performing in-situ bioremediation of the total site.

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