Cost and Performance Summary Report
Ex Situ Bioremediation of Soils at the Novartis Site, Cambridge, Ontario

Summary Information [1, 2, 3]

The Novartis site (formerly Ciba-Geigy) is located in Cambridge, Ontario. Since 1972, the site was used for formulating and warehousing of agricultural chemicals. Data obtained during characterization work performed by Ciba indicated that the site was contaminated with Metolachlor, a chlorinated herbicide.

In 1996, a pilot-scale demonstration of an ex situ bioremediation technology was conducted at the site by Grace Bioremediation Technologies (Grace) as part of a grant to complete development of the DARAMEND™ bioremediation process. The grant was funded by the Ontario Ministry of Environment and Energy's Environmental Technologies Program, Environment Canada's Development and Demonstration of Site Remediation Technologies Programs, and Grace.

The demonstration was conducted from March 1996 to September 1997. Approximately 200 tons of soil contaminated with Metolachlor were treated during this demonstration.

Timeline

February 6, 1996	Identified site for demonstration
February 23, 1996	Construction completed
Mar. 7, 1996 - Sept. 23, 1997	Demonstration conducted
September 23, 1997	Final samples collected

Factors that Affected Cost or Performance of Treatment [3, 4]

Matrix Characteristics

Listed below are the key matrix characteristics for this technology and the values measured for each.

Parameter	Value
Soil Classification:	Fine sandy loam
Clay Content and/or Particle Size Distribution:	59.6% sand, 37.5% silt, 2.9% clay
Moisture Content:	Varies*
pH:	7.8
Total Organic Carbon:	0.58%
Total Nitrogen:	< 0.01%
Available Phosphorus:	8 mg/kg

* Moisture content was 90% of water holding capacity during anoxic phase and 60% of water holding capacity during oxic phase.

Treatment Technology Description [1, 2, 3, 4]

The DARAMEND™ process is an ex situ soil bioremediation technology that has been modified by Grace to treat soils contaminated with chlorinated organics, such as organochlorine pesticides and herbicides that degrade slowly under aerobic conditions. The modified process uses organic and inorganic amendments to promote the activity of indigenous microorganisms in the soil to degrade contaminants. Microbial inoculation is not required. According to Grace, the technology has been applied to both ex situ and in situ treatment of soil. This report addresses the results of the ex situ demonstration at the Novartis site.

The treatment area included three treatment cells - the main treatment cell (Plot A), the high Metolachlor (HM) test cell (Plot B), and the static control cell (Plot C). The treatment area was lined with clay underlain with a high density polyethylene (HDPE) liner. The main treatment cell was designed to hold 180 tons of soil; the remaining cells were each designed to hold 10 tons of soil.

A 204 ft. long by 30 ft. wide greenhouse structure was constructed over the treatment area. The arches for the greenhouse were placed every four ft. along its length and secured using concrete columns (18" by 48"). The greenhouse was covered with two layers of polyethylene, separated by forced air. The HM cell and the static control cell were constructed within the treatment area. Each cell was a rectangular wood-framed box open at the top, lined with a 40 mil HDPE.

Construction of the treatment area was completed in February 1996. A total of about 200 tons of soil were placed in the treatment area including drummed soil (about 15 cu. meters) and soil from excavation activities at Novartis. The demonstration was designed to cycle between anaerobic or "anoxic" conditions and aerobic or "oxic" conditions to promote reductive dechlorination and subsequent aerobic degradation of the chlorinated pesticides. From March 7, 1996, to September 23, 1997, the soil was subjected to a total of 10 complete aerobic and anaerobic cycles. For the anaerobic cycle, DARAMEND™ amendments and inorganic amendments (for example, multivalent metal) were added to the soil, the soil was irrigated, and then covered with a tarpaulin. For the aerobic cycle, the tarpaulin was removed and the soil was tilled twice a week. No amendments were added during the aerobic cycle in this application.

According to Grace, the demonstration was originally planned for 6 cycles. However, 10 cycles were used to compensate for initial delays in startup and slightly slower than anticipated

biodegradation rates. In addition, the HM cell was tilled using a hand operated rotary tiller because of the small cell size. As a result, Grace stated that tillage was effective in the top 30 cm rather than the full 60 cm plot depth (for the HM cell only).

Operating Parameters [4]

Parameter	Value
Mixing Rate or Frequency	Twice a week during aerobic cycle
Moisture Content	Refer to matrix characteristics
pH	Varies (6 -7.8)
Temperature	Ambient (>10 ºC)
Rate of Degradation	19.4 ppm/month
Enhancement	Daramend™ (organic) and inorganic (multivalent metal)

Performance Information [1, 2, 3]

For sampling purposes, the main treatment cell was divided into five zones, and each zone was further divided into 20 equal subunits. Within each zone, five subunits were randomly selected for sampling during the course of the demonstration; these samples were composited for analysis. The HM and static control cells were not subdivided for sampling. Rather, for each sampling event, five samples were collected and composited from each of the cells.

Initial samples were collected prior to the start of treatment and analyzed for 2, 4-D, Dinoseb, Atrazine, and Metolachlor using a toxic organic (TO) Scan (EPA Method 625). Samples were also analyzed for soil physical/chemical properties, selected metals, and chloride. Samples to monitor treatment progress were collected on days 2, 7, 98, 208, 306, and 454 of the demonstration and screened for Metolachlor using a HPLC quick screening method (EPA Method SW846-8150). Final samples were collected on day 565 and analyzed in the same manner as the initial samples.

Table 1 presents the initial and final concentrations of these compounds by soil plot. Table 2 presents the progress sampling results for Metolachlor in soil by treatment area.

Table 1 - Initial and Final Concentrations of Target Compounds [3]

Plot		Initial Concentration (mg/kg)				Final Concentration (mg/kg)			
	Sample	2,4-D	Dinoseb	Atrizine	Metolachlor	2,4-D	Dinoseb	Atrizine	Metolachlor
A	Zone 1	(0.4)[1]	(0.4)	1.5	68	(1.0)	(1.0)	(1.5)	(1.0)
	Zone 2	(0.4)	(0.4)	4.7	84	(1.0)	(1.0)	(1.5)	(1.0)
	Zone 3	3.7	(0.4)	13.0	48	(1.0)	(1.0)	(1.5)	(1.0)
	Zone 4	2.8	(0.4)	17.0	54	(1.0)	(1.0)	(1.5)	(1.0)
	Zone 5	1.2	(0.4)	15.0	82	(1.0)	(1.0)	(1.5)	(1.0)
B	HM[2]	(0.4)	(0.4)	4.5	170	(1.0)	(1.0)	(1.5)	38
	HM[3]	-	-	-	-	(4.0)	(4.0)	(6.0)	11.8
C	Static control	(0.4)	(0.4)	1.0	37	2.3	(1.0)	3.9	56
	Untreated Material[4]	-	-	-	-	(1.0)	(1.0)	4.9	2.0

1 - Values in parenthesis represent MDL for compounds reported as non detectable
2 - Sample collected from entire 60 cm depth
3 - Sample collected from top 30 cm only
4 - Near berm around treatment area (uncontaminated soil)

Table 2 - Metolachlor Concentrations (mg/kg) [3]

Area	Initial	Day 2	Day 7	Day 28	Day 208	Day 306	Day 454	Day 565
Main Treatment cell[1]	67	72	65	53	27	14	3.1	ND
HM cell[2]	170	140	140	110	78	57	42	38
Static Control cell	37	NS	49	87	63	57	66	56

1- Average of 5 zones
2- Sample collected from entire 60 cm depth
NS- Not sampled
ND- Not detected (below 1.0 mg/kg)

The goal of the demonstration was to reduce the concentrations of the target organic compounds - 2, 4-D, Dinoseb, Atrizine, and Metolachlor in the treated soil (the principal target compound on which the system operation was optimized was Metolachlor). As shown in Table 1, Dinoseb was not detected in any of the initial or final samples. 2,4-D was reduced from initial concentrations as high as 3.7 mg/kg to below detection limits in Plots A and B. Atrizine was reduced from initial concentrations as high as 17.0 mg/kg to below detection limits in these plots.

As shown in Tables 1 and 2, the concentration of Metolachlor in the main treatment cell was reduced from initial levels ranging from 48 to 84 mg/kg (67 mg/kg average) to below the detection level of 1.0 mg/kg. This reduction was observed in all 5 sample zones. In the HM cell, concentrations of Metolachlor were reduced from 170 mg/kg to 38 mg/kg (a 78% reduction). According to Grace, because only the top 30 cm of soil were tilled in the HM cell (as described above), effective treatment may not have occurred throughout the cell. A final sample of the top 30 cm of the HM cell showed Metolachlor concentrations of 11.8 mg/kg, below the 38 mg/kg for the entire 60 cm sample. Metolachlor concentrations in the static control cell remained essentially unchanged (initial concentration of 37 mg/kg and a final concentration of 56 mg/kg).

Performance Data Quality [3]

According to Grace, split samples and field duplicates indicated that the data quality was generally good. The relative percent difference (RPD) was less than 20% for all progress samples. The RPD for the initial samples was high (100%). According to Grace, this high RPD was likely due to the relatively heterogeneous matrix following a single tillage event.

Cost Information [3, 4]

Specific cost information was not provided for the 200 ton demonstration. However, Grace used the results of the demonstration to project a cost of $111,600 or $186/ton (in Canadian dollars) for remediating the 600 tons of waste currently stored at the Novartis facility using DARAMEND™ bioremediation. (Based on an exchange rate of 0.65, this corresponds to a projected cost of $73,000 or $120/ton in U.S. dollars.) According to Grace, this cost was calculated by dividing the appropriate components of the project budget by the total mass of soil treated during the demonstration. Grace noted that while capital and startup costs (e.g., lease of tractor and permitting) would remain relatively constant regardless of scale, about one-third of the project budget was dedicated to items required for the demonstration (e.g., extensive process monitoring, supplemental waste analysis) that would not typically be required during commercial applications (these costs are not included in the projected costs shown above).

Grace also noted that a number of factors will affect the actual cost of using this technology on a full-scale basis at other sites. These include the site location (distance from source of equipment, supplies, and personnel, as well as climate), quantity of soil treated, initial concentrations of target compounds, applicable remediation criteria, monitoring requirements, soil pretreatment requirements, and personal protective equipment requirements. For example, Grace stated that a full-scale application involving treatment of 2,500 - 5,000 tons of waste would cost $80-125/ton (in Canadian dollars; $52-81/ton in U.S. dollars).

Observations and Lessons Learned

The modified DARAMEND™ process reduced the concentrations of Metolachlor in the main treatment cell by 99%, from initial concentrations of 67 mg/kg to below detection limits (1.0 mg/kg). Concentrations of this compound in the HM cell were reduced by 93% in the top 30 cm of soil that were tilled and by 78% in the entire 60 cm of soil in the cell. These results were achieved after 565 days of operation.

The lower reduction in the entire 60 cm depth of the HM cell was attributed by Grace to the fact that tillage was effective only to a depth of about 30 cm.

The use of alternating aerobic and anaeobic cycles appeared to promote biodegradation of chlorinated pesticides and herbicides without the use of microbial innoculum.

The time and number of cycles required for the demonstration was longer than planned. According to Grace, this was caused by initial delays in startup as well as low temperatures during the winter months that slowed biological activity.

Contact Information

For more information about this application, please contact:

David Raymond, Project Manager
Grace Bioremediation Technologies
3465 Semenyk Court
Mississauga, Ontario
Canada
Telephone: (905) 273-5374
Fax: (905) 273-4367
E-mail: david.raymond@grace.com

References

The following references were used in the preparation of this report.

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2. Ex-situ Bioremediation of Soils Containing Metolachlor: Pilot-Scale Demonstration at Ciba-Geigy Facility, Cambridge, Ontario. Second Interim Report. Prepared by GRACE Bioremediation Technologies. February 1997.

3. Ex-situ Bioremediation of Soils Containing Metolachlor: Pilot-Scale Demonstration at Ciba-Geigy Facility, Cambridge, Ontario. Draft Final Report. Prepared by GRACE Bioremediation Technologies. February 1998.

4. Comments provided by David Raymond, Grace Bioremediation Technologies on Draft Cost and Performance Summary Report. October 7, 1998.

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