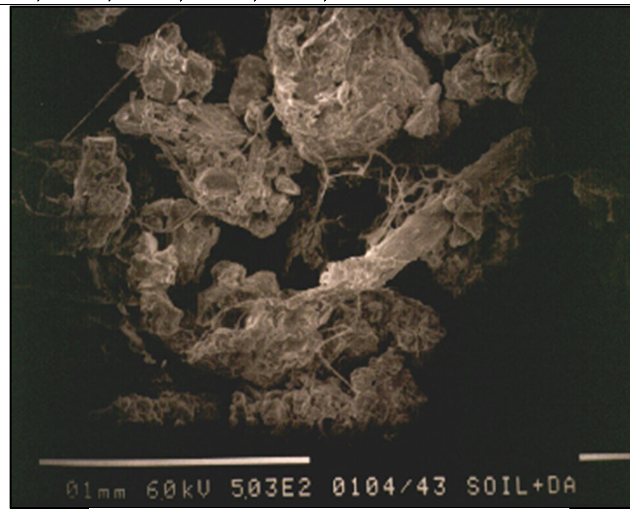
POPS - WASTES APPLICABILITY (REFS. 1, 6, AND 10):
DARAMEND® is a bioremediation technology that has been used to treat soils and sediments containing low concentrations of pesticides such as toxaphene and DDT as well as other contaminants.

POPs Treated:	Toxaphene and DDT
Other Contaminants Treated:	DDD, DDE, RDX, HMX, DNT, and TNT

TECHNOLOGY DESCRIPTION (REFS. 4, 5 AND 10):
OVERVIEW

DARAMEND® is an amendment-enhanced bioremediation technology for the treatment of POPs that involves the creation of sequential anoxic and oxic conditions. The treatment process involves the following:

1. Addition of solid phase DARAMEND® organic soil amendment of specific particle size distribution and nutrient profile, zero valent iron, and water to produce anoxic conditions.
2. Periodic tilling of the soil to promote oxic conditions.
3. Repetition of the anoxic-oxic cycle until the desired cleanup goals are achieved.



DARAMEND® particle colonization as viewed through an electron-microscope

The addition of DARAMEND® organic amendment, zero valent iron, and water stimulates the biological depletion of oxygen generating strong reducing (anoxic) conditions within the soil matrix. The diffusion of replacement oxygen into the soil matrix is prevented by near saturation of the soil pores with water. The depletion of oxygen creates a very low redox potential, which promotes dechlorination of organochlorine compounds. A cover may be used to control the moisture content, increase the temperature of the soil matrix and eliminate run-on/run off. The soil matrix consisting of contaminated soil and the amendments is left undisturbed for the duration of the anoxic phase of treatment cycle (typically 1- 2 weeks).

In the oxic phase of each cycle, periodic tilling of the soil increases diffusion of oxygen to microsites and distribution of irrigation water in the soil. The dechlorination products formed during the anoxic degradation process are subsequently removed trough aerobic (oxic) biodegradation processes, initiated by the passive air drying and tilling of the soil to promote aerobic conditions.

Addition of DARAMEND® and the anoxic-oxic cycle continues until the desired cleanup goals are achieved. The frequency of irrigation is determined by weekly monitoring of soil moisture conditions. Soil moisture is maintained within a specific range below its water holding capacity. Maintenance of soil moisture content within a specified range facilitates rapid growth of an active microbial population and prevents the generation of leachate. The amount of DARAMEND® added in the second and subsequent treatment cycles is generally less than the amount added during the first cycle.

DARAMEND® technology can be implemented using land farming practices either ex situ or in situ. In both cases, the treatment layer is 2 feet (ft) deep, the typical depth reached by tilling equipment. However, the technology can be implementation in 2-ft sequential lifts. In the ex situ process, the contaminated soil is excavated and sometimes mechanically screened in order to remove debris that may interfere with the distribution of the organic amendment. The screened soil is transported to the treatment unit, which is typically an earthen or concrete cell lined with a high-density polyethylene liner. In situ, the soil may be screened to a depth of 2-ft using equipment such as subsurface combs and agricultural rock pickers.

STATUS AND AVAILABILITY (REF. 1):
DARAMEND® is a proprietary technology and is available only through one vendor - Adventus Remediation Technologies (ART), Mississauga, Ontario, Canada. In the U.S., the technology is provided by ART's sister company, Adventus Americas Inc., Bloomingdale, IL. The technology has been used for the treatment of POPs (toxaphene and DDT) since 2001. Table 1 lists performance data for DARAMEND® technology application at selected sites. Through 2005, DARAMEND® has been implemented at two POPs contaminated sites.

Table 1: Performance Data of DARAMEND at Selected Sites

Site Name	Scale	Quantity Treated (tons)	No. of treatment cycles	Duration of each cycle	Cost per ton*	Performance		
						Contaminant	Untreated Concen-tration (mg/kg)	Treated Concen-tration (mg/kg)
POPs Contaminated Sites								
T.H. Agricultural & Nutrition (THAN) Superfund Site, Montgomery, Alabama	Full	4,500	15	10 days	$55	Toxaphene DDT DDE DDD	See Table 2 for performance data	
W.R. Grace, Charleston, South Carolina	Pilot	250	8	1 month	$95	Toxaphene	239	5.1
						DDT	89.7	16.5
Non-POPs Contaminated Sites								
Naval Weapons Station,Yorktown, Virginia	Full	4,800	12	7-10 days	$90	TNT	15,359	14
						RDX	1,090	1.6
						DNT	1,002	13
Iowa Army Ammunition Plant, Burlington, Iowa	Full	8,000	5	7-10 days	$150	RDX	1,530,	16.2
						HMX	1,112,	84.5
						TNT	95.8	8
Confidential Site, Northwest U.S.A. (applied in multiple 2-ft lifts)	Full	6,000	Aerobic treatment	N/A	$37	PCP	359	8
						PCP	760	31

Source: Ref. 1
** Treatment costs are as reported by vendor. The vendor did not specify what was included in this cost.*

DESIGN (REF. 5):
The major design factor for the implementation of this technology is the amount and type of soil amendments required for bioremediation. This is dependent on site conditions and the physical (textural variation, percent organic matter, and moisture content) and chemical (soil pH, macro and micronutrients, metals, concentration and nature of contaminants of concern) properties of the target soil. The duration of the treatment cycle is based on soil chemistry, concentration of contaminants of concern and soil temperature. The number of treatment cycles is based on the required cleanup levels of the contaminant.

THROUGHPUT (REF. 4):
For ex situ treatment, the amount of POPs contaminated soil/sediment that can be treated is dependent on the available surface area to spread contaminated soil. The technology can also be applied ex-situ in windrows. For in-situ application, the tillage equipment limits the depth (2-ft) to which the soil can be remediated. However, the technology can be used in-situ at depth greater than 2-ft using alternative soil mixing equipment or injection techniques.

WASTES/RESIDUALS (REF. 4):
The primary wastes generated are debris, stone, and construction material that are removed in the pretreatment process. No leachate is generated if a treatment area cover is used. If no cover is used, precipitation in the treatment area may generate leachate or storm water run-off.

Sampling and monitoring activities of the treatment pile will generate personal protective equipment (PPE) and contaminated water from decontamination activities.

MAINTENANCE:
Implementation of the DARAMEND® technology to treat POPs requires limited maintenance such as the upkeep of tilling, soil moisture control, and other industrial equipment. Because the specific amendments and application rate of DARAMEND® are site and soil-specific, the ongoing maintenance will vary by site and type of soil treated.

LIMITATIONS (REFS. 4 AND 9):
DARAMEND® technology may become technically or economically infeasible when treating soils with excessively high contaminant concentration. The technology has not been used for the treatment of other POPs such as PCBs, dioxins, or furans. ART, the developer of the technology, indicated that it has been only marginally successful in bench scale treatment of PCB-contaminated soil. Bench scale or pilot scale studies are typically conducted before field application of this technology; the type and amount of soil amendments required are then based on the results of these studies.

In situ application of this technology using tilling equipment is limited to a depth of 2-ft. However, the technology can be used in situ at depths greater than 2-ft using alternative soil mixing equipment or injection techniques. This technology requires that the treatment area be free of surface and subsurface obstructions that would interfere with the soil tilling. Ex situ application of this technology requires a large surface area to treat large quantities of the contaminated soil. Implementation of this technology in 2-ft sequential lifts would increase the total time required to treat the contaminated soil. The technology can also be applied ex situ in windrows.

Application of this technology requires a source of water (either city, surface, or subsurface).

This technology cannot be applied to sites that are prone to seasonal flooding or have a water table that fluctuates to within 3-ft of the site surface. These conditions make it difficult to maintain the appropriate range of soil moisture required for effective bioremediation, and may redistribute contamination across the site.

Volatile organic compound emissions may increase during soil tilling. Other factors that could interfere with the process would be large amounts of debris in the soil, which would interfere with the incorporation of organic amendments and reduce the effectiveness of tilling. Presence of other toxic compounds (heavy metals) may be detrimental to soil microbes. Soils with high humic content may slow down the cleanup through increased organic adsorption and oxygen demand.

FULL-SCALE TREATMENT EXAMPLES (REF. 3):

Bioremediation of pesticides-impacted soil/sediment, T.H. Agriculture and Nutrition (THAN) Superfund Site, Montgomery, Alabama.

The THAN site is located on the west side of Montgomery, Alabama, about 2 miles south of the Alabama River. The site is approximately 16 acres in area. Previous site operations involved the formulation, packing and distribution of pesticides, herbicides, and other industrial/waste treatment chemicals. The site was listed on the National Priorities List (NPL) on August 30, 1990. In 1991, EPA entered into a consent agreement with Elf Atochem North America Inc., the Potentially Responsible Party (PRP) for the site, to conduct a remedial investigation/feasibility study for the site. The final Record of Decision (ROD) for the site was signed on September 28, 1998, and bioremediation was selected as the remedy for treating the contaminated soils and sediments. DARAMEND® was selected as the bioremediation technology.

The contaminated soil and excavated sediments (approximately 4,500 tons) were treated using anaerobic/aerobic bioremediation cycle using DARAMEND®. Implementation of the technology involved the following steps:

1. DARAMEND® amendment and powdered iron application and incorporation
2. Determination of water holding capacity (first cycle only)
3. Determination of treatment matrix moisture content
4. Irrigation
5. Measurement of soil redox potential
6. Soil allowed to stand undisturbed for anoxic phase (approximately 7 days)
7. Soil tilled daily to generate oxic condition (approximately 4 days)
8. Steps 1, and 3 to 7 were repeated for each subsequent cycle. Fifteen treatment cycles were implemented in some treatment areas on site.

Two agricultural tractors (Model: Massey-Ferguson 394 H) mounted with deep rotary tillers were used for amendment application and tilling the treatment area. The target soil moisture content at the beginning of each cycle was approximately 33% (dry wt. basis) or 90% of the soil's water holding capacity. The optimal pH range (6.6 to 8.5) of the treatment area was maintained by adding hydrated lime at a rate of 1,000 mg/kg during the oxic phase of the third, sixth, and twelfth cycle. Following the application of each treatment cycle, samples were collected from the treatment area. The treatment area was divided into 12 sampling zones and one composite sample (composite of four grab samples) was collected from each zone. The samples were collected from the full 2-ft soil profile of treatment area. Fifteen treatment cycles were applied to some areas of the site. Table 2 lists the initial and final concentration of the samples collected from these 12 zones.

Based on the final sampling event DARAMEND® reduced the concentration of all the contaminants of concern to less than the specified performance standards. The average treatment cost in USD at the THAN site was $55 per ton. The vendor did not specify what was included in this cost.

Table 2: DARAMEND® performance at the THAN Site

Sampling Zone	Toxaphene (29 mg/kg)[1]		DDT (94 mg/kg)[1]		DDD (94 mg/kg)[1]		DDE (133 mg/kg)[1]	
	Initial[2] Conc. (mg/kg)	Final[3] Conc. (mg/kg)	Initial[2] Conc. (mg/kg)	Final[3] Conc. (mg/kg)	Initial[2] Conc. (mg/kg)	Final[3] Conc. (mg/kg)	Initial[2] Conc. (mg/kg)	Final[3] Conc. (mg/kg)
1	77	< 20	126	10.2	52	26.4	33	6
2	260	< 21	227	15	133	73	35.3	8.4
3	340	< 21	33.2	4.5	500	89	49	7.8
4	45	< 21	55.1	14.7	34	37	15.8	7.2
5	230	< 21	216	16.1	93	53	22.4	6.8
6	90	< 21	13.3	2.2	130	59	17	5.7
7	100	< 20	151	15.3	85	38	25.2	6.3
8	13	< 20	9.1	5.2	44	24.3	6.9	2.8
9	330	< 21	45	5.7	312	85	28.2	7.2
10	48	< 20	44.4	5.7	146	25.5	20.1	4.2
11	20	< 20	12.6	2.9	46	25.1	6.9	3.0
12	720	< 21	78	6.3	590	87	59.6	8.6

Notes:
1. Performance Standard as specified in the Record of Decision, Summary of Remedial Alternatives Selection, THAN Site.
2. Initial concentration reported from samples collected by responsible party.
3. Final concentration reported from splits samples collected by EPA.

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PATENT NOTICE:
DARAMEND® is a patented technology with U.S. Patent No. 5,618,427.

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