

Introduction

This document summarizes Adventus experience treating organochlorine pesticides (OCPs) in soil and groundwater using DARAMEND® and EHC® bioremediation amendments. Adventus has offered DARAMEND for ex situ treatment of recalcitrant compounds in soil for more than 10 years. DARAMEND has also shown to be effective for *in situ* applications. As OCPs bind strongly to the soil, the impacts are often limited to the upper couple of feet and regular agricultural equipment could be used for *in situ* application of the DARAMEND amendments. Variations of these materials have also been found effective for in situ treatment of OCPs in groundwater. EHC and DARAMEND are also effective for treatment of a number of other inorganic and organic compounds and could hence be used for mixed impacts. In addition, formulations of these compounds are available for simultaneous immobilization of heavy metals such as arsenic, chromium and lead.

DARAMEND for OCPs in Soil

DARAMEND is an advanced biological treatment technology for soil, sediment and solid wastes contaminated with recalcitrant organic compounds. DARAMEND has been successfully applied to more than 2,000,000 tons of soil, sediment, and other materials contaminated with persistent compounds including polynuclear aromatic hydrocarbons (PAHs), PCP, phthalates, chlorinated herbicides and pesticides, organic explosive compounds and wood preservatives at a variety of industrial and Department of Defense (DOD) sites in the United States, Canada, and Europe. Given our excellent record of performance, **Adventus is willing to guarantee the remedial performance** of our technology.

The key components of DARAMEND bioremediation technology are (i) amendment of the material to be remediated with DARAMEND organic amendments, and (ii) regulation of oxygen availability and moisture content by mechanical tillage and irrigation, respectively. The treatment schedule and the exact formula of the DARAMEND amendments vary depending on the compound to be treated. For OCPs, an approach with cycled anaerobic and aerobic conditions have been found to be the most effective and the DARAMEND amendments are comprised of organic material, and reduced iron and/or reduced zinc. The organic fraction is derived from natural plant fibers rich in cellulose and hemicellulose, and therefore serves as a carbon source for microbiological consumption. DARAMEND also provides major, minor and micro nutrients required for rapid microbial growth. DARAMEND bioremediation enhances and promotes natural bioremediation rates by adjusting conditions in a soil matrix to stimulate biodegradation of target compounds. No microbial inoculation is conducted. The amendments will be manufactured regionally (Illinois or Iowa) using a proprietary process.

Ex Situ Applications

Traditionally, DARAMEND has been applied to excavated soil in on-site biotreatment cells. Adventus recently completed the full-scale remediation of a pesticide impacted superfund site in Montgomery, Alabama. At this site Toxaphene, DDT, DDD, and DDE were remediated in a land treatment cell over an average of 8 treatment cycles. The results from this project as well as a few other pesticide projects recently completed using DARAMEND bioremediation are highlighted in **Table 1** and **Appendix A**.



Figure 1: Placement of soil into treatment cell.

Table 1: Influence of DARAMEND bioremediation on OCPs in soils at sites in the USA and Canada.

Site	Compound	Concentration (mg/kg)		Treatment Period
		Initial	Final	
Uniroyal Chemical, Ontario, Canada	2,4-D	97	3.8	9 months
	2,4,5-T	8.1	1.3	
	DDT	53.5	4.7	
CIBA-Giegy, Ontario, Canada	Metolachlor	72	<1	10 months
	Atrazine	15	<1.5	
W.R. Grace, South Carolina, USA	Toxaphene	239	5.1	4 months
	DDT	89	16.5	
THAN Superfund Site, Alabama, USA	Toxaphene	189	11	10 months
	DDT	84	9	
	DDD	180	52	
	DDE	25	6	
ATOFINA Chemicals Kentucky, USA	a-HCH	7,647	446	99 days
	b-HCH	1,200	373	
	Lindane	567	14	
	d-HCH	747	57	
	HCB	10.9	1.3	

In Situ Treatment of OCPs in Soil

DARAMEND bioremediation can also be effectively applied *in situ* as a land treatment process. Soil and amendments are blended using a rotary tiller, driven by an agricultural tractor, with an effective penetration of 2 ft. Deeper soil impacts may be treated *in situ* using deep soil mixing equipment or by applying the treatment in lifts. Depending on the cost of excavation and the depth of contamination this may be more cost effective than ex-situ treatment. Water content is one critical process parameter and is adjusted using agricultural irrigation equipment. The results from a couple of *in situ* projects are provided in **Table 2**.



Figure 2: Application of DARAMEND.



Figure 3: Irrigation to add moisture.

Table 2: Influence of DARAMEND bioremediation applied *in situ*.

Site	Compound	Concentration (mg/kg)		Treatment Period
		Initial	Final	
Agricultural Site, Florida, USA	Dieldrin	45.9	15.1	2 weeks
Future Residential Development Site, CA (confidential)	DDT	2.0	0.33	3 weeks
	DDE	3.1	0.7	
	DDD	0.07	0.025	

EHC for OCPs in Groundwater

EHC is a patented combination of controlled-release carbon and zero-valent iron (ZVI) particles used for stimulating reductive dechlorination of otherwise persistent organic compounds in groundwater. EHC uses the same basic chemistry as DARAMEND, but is specifically formulated for easy injection into the subsurface. EHC is provided in 50-lb bags as a dry powder and mixed with water on site into a slurry. The slurry is injected into the subsurface using a number of available technologies, including direct injection through GeoProbe rods and hydraulic/pneumatic fracturing. EHC slurry may also be applied via direct application into trenches or by using deep soil mixing equipment. Common applications include hot-spot treatment, plume treatment and plume management using a permeable reactive barrier.

Relevant Treatment Performance

EHC has been evaluated at both bench and field scale for treatment of various OCPs in groundwater (**Table 3**). Please note that the results refer to a single application of EHC and the treatment time refers to the elapsed time post application. More detailed information is provided for a couple of the projects in **Appendix B**.



Table 3: Influence of EHC bioremediation on OCPs in groundwater/saturated soils at sites in the USA.

Site	Compound	Concentration		Treatment Period
		Initial / Control	Final / Latest Data	
Pilot-Scale PRB, Pesticide Manufacturing Facility, California, USA	Dibromochloropropane [ug/L]	1.5	0.26	Still ongoing - 5 months
	Ethylene dibromide [ug/L]	1.5	0.5	
	Nitrate-nitrogen [mg/L]	240	20	
Plume Treatment using 3 Reactive Zones, Former Pesticide Manufacturing Facility, SE USA	Endrin [ug/L]	20.5	0.6	Batch study (detects) – 4 days
	pp'-DDD [ug/L]	1.3	ND	
	pp'-DDT [ug/L]	11.9	ND	
	Endrin Ketone [ug/L]	1.4	ND	
	Total BHCs [ug/L]	1.1	0.51	Field data (mean conc.) - 6 months
	Dieldrin [ug/L]	0.60	0.19	
	Endrin [ug/L]	0.58	0.36	Field data (mean conc.) - 10 months
	Total BHCs+ Dieldrin+Endrin [ug/L]	2.3	1.1	
Hot-Spot Treatment, Former Pesticide Manufacturing Facility, SE USA	Toxaphene [mg/kg]	127.7	8.7	Mean conc. in saturated soil – 8 months
	Total OCPs [mg/kg]	169.1	11.8	