Introduction

This document summarizes our experience treating organochlorine pesticides (OCPs) in soil and groundwater using Daramend® and EHC® reagents. Daramend has been used for *ex situ* treatment of recalcitrant compounds in soil for more than 20 years. 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 Daramend reagent. EHC reagent, a variation of the Daramend technology, has 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 impacted areas of mixed type of contamination. 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 a technology for soil, sediment, and solid wastes contaminated with recalcitrant organic compounds. Daramend has been successfully applied to more than 10,000,000 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.

The key components of the Daramend technology treatment process are (i) application of the Daramend reagent to the material to be remediated, and (ii) regulation of oxygen availability and moisture content by mechanical tillage and irrigation, respectively. The treatment schedule may vary depending on the compound to be treated and if any site specific modifications to the Daramend reagent have been made. For OCPs, an approach with cycled anaerobic and aerobic conditions have been found to be the most effective.

Daramend is comprised of organic material, and reduced metals (typically zero-valent iron particles 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 enhances and promotes natural bioremediation rates by adjusting conditions in a soil matrix to stimulate biodegradation of target compounds. No microbial inoculation is conducted.

Ex Situ Applications

Traditionally, Daramend has been applied to excavated soil in on-site biotreatment cells. An example of this is the application at a superfund site in Montgomery, Alabama where Daramend was used to remediate soil impacted by Toxaphene, DDT, DDD, and DDE. Impacted soil was excavated and 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 are highlighted in **Table 1.**

Figure 1: Placement of soil into treatment cell

Table 1: Influence of Daramend reagent 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	
CIB-Giegy, Ontario, Canada	Metolachlar	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 can also be effectively applied *in situ* as a land treatment process. Soil and reagents 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 select *in situ* projects are provided in **Table 2**.

Figure 2: Application of Daramend

Figure 3: Irrigation to add moisture

Table 2: Influence of Daramend reagent 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 Reagent for OCPs in Groundwater

EHC reagent is a 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 (**Figure 4** and **5**). The slurry is injected into the subsurface using a number of available technologies, including direct injection 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.

Figure 4: Addition of EHC to prepare slurry.

Figure 5: EHC slurry ready for injection.

Relevant EHC 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.

Table 3: Influence of EHC reagent 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-nitogen [mg/L]	240	20	
Plume Treatment using 3 Reactive Zones, Former Pesticides 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	
	Total BHCs+ Dieldrin+Endrin [ug/L]	2.3	1.1	Field data (mean conc.) 10 months
Hot-Spot Treatment Former Pesticide Manufacturing Facility, SE USA	Toxaphene [mg/L]	127.7	8.7	Mean conc. in saturated soil 8 months
	Total OCPs [mg/L]	169.1	11.8	