United States
Environmental Protection
Agency

SITE Technology Capsule

Dredged Material Reclamation at the Jones Island Confined Disposal Facility

U.S. Army Corps of Engineers

Abstract

In this SITE demonstration, phytoremediation technologies were applied to contaminated dredged materials from the Jones Island Confined Disposal Facility (CDF) located in Milwaukee Harbor, Wisconsin (Figure 1). The Jones Island CDF is an active facility, having received dredged materials from normal maintenance of Milwaukee's waterways and tributaries for many years. Like many CDFs across the country, Jones Island faces the dilemma of steady inputs and no feasible alternative for expansion. One option for optimizing existing CDF space is to "beneficially reuse" the dredged sediments, which effectively allows for a recycling of the sediments and the available CDF space. The U.S. Army Corps of Engineers (USACE), in partnership with the Milwaukee Port Authority, is exploring several beneficial reuse options for the dredged material, including use as building materials, road fill, landscaping soil, etc. However, direct beneficial reuse is not possible because a significant portion of the dredged material is considered contaminated and must be cleaned before it can be reused.

Dredged material at Jones Island is similar to many other CDFs in that the soil, pore water, and entrained contaminants are often very heterogeneous. Dredged materials used in the SITE demonstration were contaminated with polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and diesel-range organics (DRO) at levels exceeding relevant Wisconsin Department of Natural Resources (WDNR) and USEPA standards.

The SITE program and USACE evaluated the demonstration for two growing seasons. The effectiveness of the treatments was monitored directly through soil and irrigation water sampling and analysis and indirectly via the assessment of plant root and shoot growth. Weather data was gathered to help establish irrigation schedules. At the end of the second growing season, residual organic contaminant levels were compared against guidelines suggested by the WDNR for gauging beneficial use options.

This Technology Capsule presents the results from data collecting efforts to date. The project has demonstrated success in establishing viable growing conditions and meeting several guideline targets. The system has also been evaluated on seven criteria used for decision-making in the Superfund feasibility study process. Results of that evaluation are summarized in Table 1.

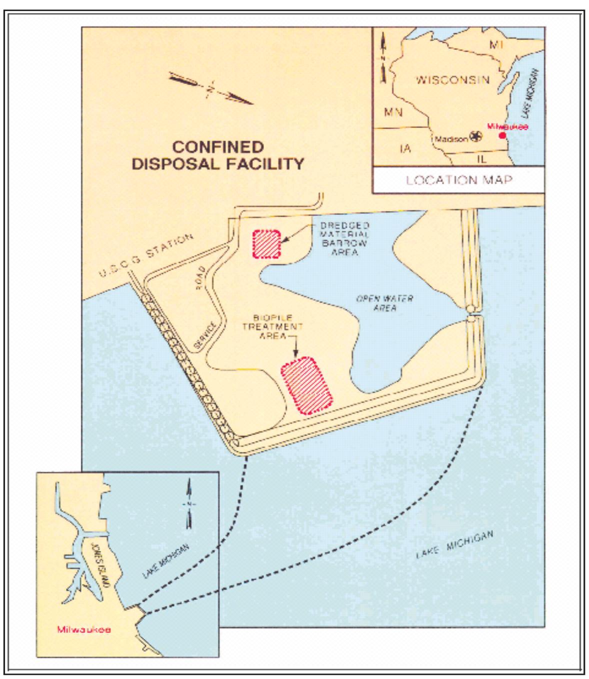

Figure 1. Location of Jones Island CDF

Introduction

In 1980, the U.S. Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, which is committed

Table 1. Feasibility Study Criteria for the Jones Island Reclamation Project.

	Criterion	Performance
1	Overall Protection of Human Health and the Environment	Protects human health and the environment by degrading organic contaminants in soil. lmpacts from excavation should be minimized through the use of engineering controls.
2	Compliance with Federal ARARs	Specific ARARs for dredged material not yet available. PCBs must comply with 40 CFR 761.61(a)(4)(i)(A). Construction activities may require permits.
3	Long-Term Effectiveness and Permanence	Permanently reduces (through biological destruction) contamination from the affected soil matrix. End-of-treatment residuals (biomass) are non-hazardous.
4	Reduction of Toxicity, Mobility, or Volume Through Treatment	Toxicity of contaminants minimized by treatment
5	Short-Term Effectiveness	Aesthetically pleasing solution that presents minimal risk to workers and the community.
6	Implementability	Implementation needs vary with application. Requires minimal site utilities.
7	Cost	Approximately $20/ton for corn or willow treatment on a per acre basis.

to protecting human health and the environment from uncontrolled hazardous waste sites. CERCLA was amended by the Superfund Amendments and Reauthorization Act (SARA) in 1986 to emphasize long-term effectiveness and permanent solutions with a preference for alternative treatment technologies or resource recovery to the maximum extent possible.

The U.S. Environmental Protection Agency (EPA) has focused on policy, technical, and awareness issues related to new remediation technologies. A prominent response to these issues is EPA's Superfund Innovative Technology Evaluation (SITE) program, which was established to accelerate development, demonstration, and use of innovative technologies for site clean-ups. EPA SITE Technology Capsules summarize the latest information available on these technologies. These Capsules are designed to help EPA Remedial Project Managers and On-Scene Coordinators, contractors, and other site clean-up managers understand the types of data and site characteristics needed to evaluate a technology's suitability for Superfund cleanup.

This Capsule provides information about the dredged material reclamation field demonstration on the Jones Island CDF. The project goal was to determine if either cultivated or indigenous plants could reduce the level of organic pollutants in dredged material and permit their offsite use in some beneficial capacity. Information provided in this SITE Technology Capsule is based on results from the testing period June 2001 through September 2002.

Details are presented in the following format:

- Abstract
- Technology description
- Technology applicability
- Technology limitations
- Process residuals
- Site requirements
- Performance data
- Technology status
- Source of further information

Technology Description

Phytoremediation, or phytotechnologies, are current defined as the use of vegetation to contain, sequester, remove, or degrade organic and inorganic contaminants in soils, sediments, surface water, and groundwater. Six different plant-facilitated processes have been recognized as contributing to phytoremediation success. These processes are as follows:

- Phytoaccumulation, referring to a process where plant roots uptake and translocate contaminants (typically metals and radionuclides) to their above-ground biomass where they are concentrated and can be harvested and disposed of.
- Rhizostabilization, which refers to a process whereby contaminants (typically metals) are sorbed onto plant roots and therefore not available for migration,
- Rhizodegradation, which describes the complex interactions of roots, root exudates, and the surrounding soil and microbial community, and how these interactions can break down contaminants, (typically organics) in situ to less toxic or non-toxic by-products,
- Phytodegradation, which describes processes occurring inside the plant which can degrade or detoxify contaminants, (usually organics)
- Phytovolatilization, referring to the process whereby contaminants are extracted from soil or ground water and then transferred into the atmosphere via evapotranspiration processes, (more typical of organics)
- Phytostabilization, which describes how certain plants which have high water use (typically trees) can slow or reverse ground water flow paths thereby containing, and often remediating, contaminated groundwater plumes.

Of these six processes, rhizodegradation is emerging as one of the most important, and complex, means by which plants degrade contaminants, especially large molecule organics like PAHs and PCBs found at the Jones Island CDF.

The first step taken on this project toward determining appropriate beneficial end use of the dredged material present in the CDF was a detailed characterization across the CDF with samples taken at three intervals below ground surface and analyzed for PAHs, PCBs, and agricultural parameters. The analytical results confirmed a wide variety of contaminant concentrations and also indicated areas of opportunity for phytoremediation.

Treatability studies conducted at the USACE Engineer Research and Development Center (ERDC) in 2000 by the technology developer using crops and grasses determined that plants would survive in the material and degrade the contaminants. Over the short test period, a fast-maturing corn hybrid showed the highest reduction effect.

In June 2001, four field plots containing four treatment cells each were established on the CDF by excavating, screening, and depositing soil in the cells. The test plots closely followed the Remediation Technology Development Forum (RTDF) protocol for plot size, sampling, and statistical design. The RTDF Protocol is available at http://www.rtdf.org/public/phyto/protocol/protocol99.htm. Each plot had four randomized treatments: the corn hybrid, sandbar willow, local grasses, and an unplanted control (aka, plant suppression). Corn was planted twice during the growing season, which was designated as June through September.

Figure 2 shows an "as-built" layout of the Jones Island test plots and irrigation system. This photo was taken during the an early stage of the first growing season in 2001. Figure 3 is a schematic of a nominal test plot/treatment cell configuration including construction details.

Technology Applicability

Aged dredged material at Jones Island is heterogeneous in composition because it comes from waterway sources over a wide area over many years. Some dredged materials contain EPA listed wastes from industrial discharge, spills, and urban run-off in widely varying concentrations. Natural attenuation processes occur at differing rates due to random placement in the CDF and various oxygen and moisture levels and weathering impacts.

A biomound study conducted by the USACE Detroit District in 1998 at the Jones Island CDF concluded that there were indigenous microorganisms within the dredged material capable of degrading PAH and PCB compounds. During 2000 the ERDC conducted a series of greenhouse trials to evaluate the ability of different plant varieties to enhance the action of the local microbes and further reduce the level of PAHs and PCBs in Jones Island dredged materials. Prior to the trials, the ERDC performed an extensive literature search for plants that showed an ability to treat PAHs and PCBs and could grow well in Milwaukee's climate during the spring and summer months. A number of candidate plants were identified and tested in combination with different soil amendments (Figure 4). Results show the best reductions were achieved with a corn hybrid, which reduced the concentration of PAHs and PCBs by 78% and 64%, respectively on unamended dredged material.

Figure 2. Layout of treatment plots at Jones Island CDF

In Spring 2001 the ERDC conducted a brief floristic survey of the Jones Island CDF for the purpose of identifying the types of natural vegetation that might develop during this SITE demonstration. The ERDC reported that the CDF naturally supports dense native (annual and perennial) vegetation during the growing season, and identified 85 species of vascular plants. In the older areas of the CDF, on sediment that may have exceeded 10 years of age, the dominant vegetation was *Phalaris arundinacea* (Reed Canary Grass), *Salix interior* (Sandbar Willow), and *Urtica procera* (Tall Nettle). Dredged material used for this demonstration came from one of these older areas.

Technology Limitations

The most significant limitation to successful phytotechnology is plant mortality. While plants need not necessarily be in perfect or optimum health to perform satisfactorily, they must be living. Therefore, plant stress, whether it arises from extreme contamination levels, poor quality soils, inadequate moisture, disease or pests, must be prevented. Inadequate root development can pose a limitation to phytoremediation effectiveness. Root mass must develop sufficiently to reach and achieve an effect on pollutants. For the Jones Island project, root depth is not a key factor since the soil in the cells was less than 30 cm (12 in) deep (easily within the reach of plant roots), and are not likely to be much deeper in a full scale operation. Depending on plant spacing, lateral root development can be important. Planting density should be high enough for full subsurface coverage at crop maturity, and for full above ground canopy closure to crowd out weeds that compete for space and resources (i.e. water, nutrients, and sunlight).

In general, the growing season at the Jones Island CDF is expected to commence in May. October typically brings colder weather that is unsuitable for growing the types of plants involved in this demonstration and limits effectiveness over these months. However, rhizosphere processes can continue for short periods without active shoots, offering some degree of remedial benefit even during dormant periods.

Process Residuals

The biomass generated as plants mature is a process residual. For this project corn biomass was tilled back into the test material prior to the next planting event and consumed biologically during the next growing cycle. No net corn biomass was generated. Although Sandbar willows were found growing

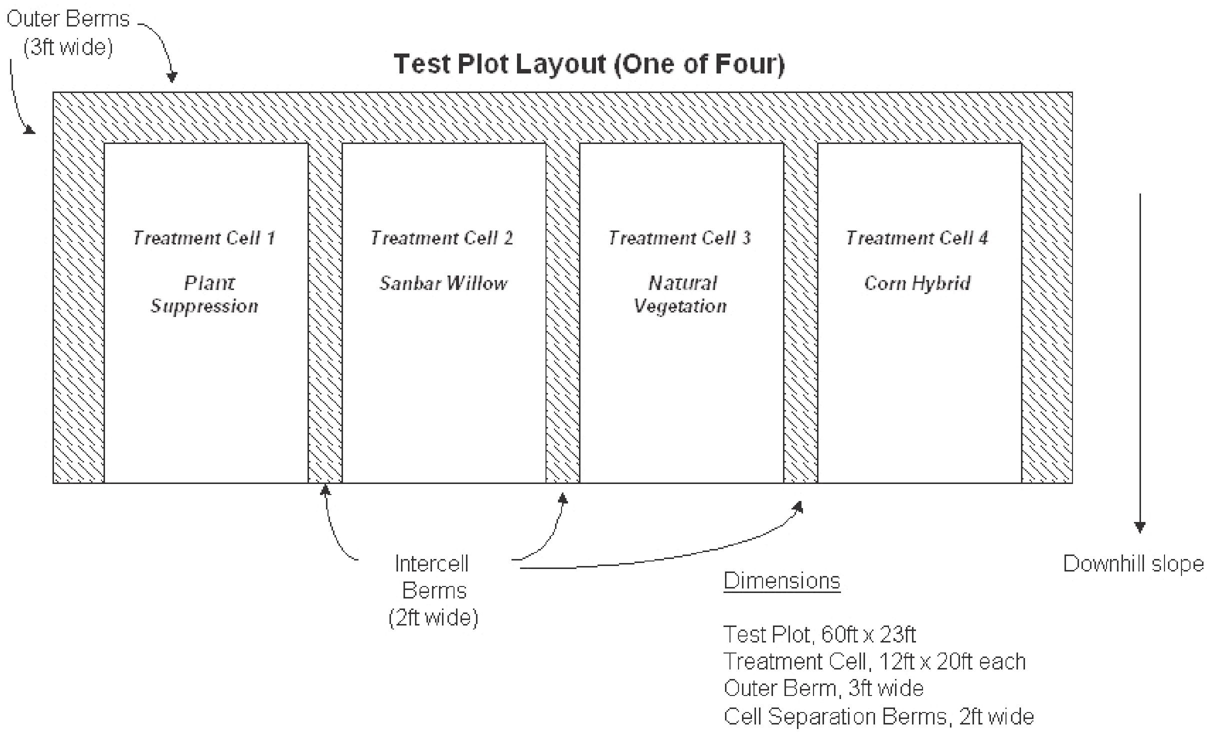

Figure 3. Configuration of test plot/treatment cells

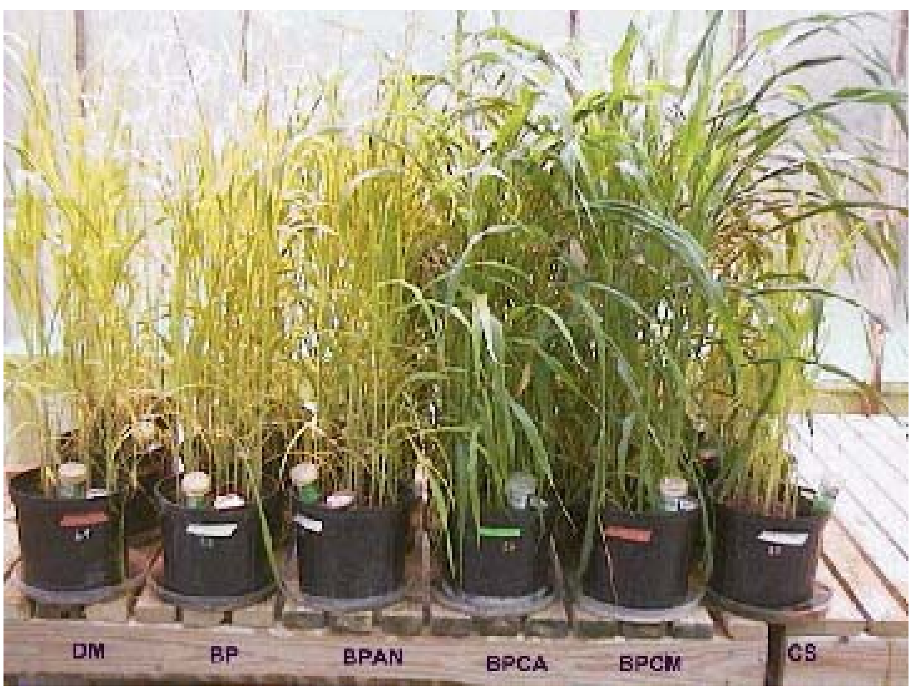

Figure 4. ERDC greenhouse soil/amendment experimentation

naturally on the CDF, the ones used in this field demonstration will be harvested ultimately. The accumulated biomass may chipped and disposed of or recycled for landscaping purposes offsite.

Site Requirements

Site support requirements for phytoremediation systems occasionally include one or more of the following:

- Electricity to run groundwater pumps or other circulatory system, which can be utility-connected or solar powered
- Water, for irrigation, which may be spray, flood, or drip-applied, and may be contaminated or clean in origin
- Any equipment deemed necessary for site monitoring and maintenance (e.g. soil moisture probes, sap flow equipment, data loggers, telemetry)
- Perimeter fencing, depending on the site location, plant sensitivity hazard analysis, etc.

Generally, any given location which supports or can support plant life probably has characteristics suitable for some form of phytotechnology application. However, while the range of suitable site characteristics is wide, there are significant limitations to the technology, as described previously.

To determine the suitability of the dredged materials at the Jones Island CDF, grab soil samples were collected and analyzed for various agronomic parameters as part of a scoping study in September 2000. Similar sampling and analysis was performed again at the start of the test period in June 2001. Table 2 compares results from the eventual borrow area (GP17 and GP19) identified during the scoping study with the mean (n=16) of baseline sampling after the dredged material was placed into the treatment cells (before fertilizer was applied). The data between the two sampling events agrees well and was considered suitable by the USACE for the purposes of this field demonstration.

Insect attack and available responses may limit plant choices from both a physical and regulatory standpoint. During the second half of the 2002 growing season, the hybrid corn crop and adjacent natural vegetation became infested with the Western Corn Rootworm Beetle (*Diabrotica virgifera virgifera*). The pest is well known in agriculture, and a number of commercial pesticides are available as well as other natural organic and biological controls, all with varying degrees of predicted success. Sevin, a non-restricted carbamate insecticide available at local garden shops, was selected for use at the demonstration site. A license was not required for its use. Several applications were required.

Table 2. Borrow Area and Baseline Agronomic Parameters.

Parameter	Borrow Area GP17	Borrow Area GP19	Baseline Mean
Soil pH	8.2	7.9	8.6
Soluble Salts (mmhos/cm)	0.37	0.33	0.61
Excess Lime	Hi	Hi	Hi
Organic Matter (%)	3.8	5.0	4.1
Nitrate-Nitrogen	3	3	9.5
Phosphorous	58	69	63
Potassium	80	140	100
Sulfur	37	17	49
Calcium	4100	4100	4300
Magnesium	160	190	140
Sodium	170	31	610
Zinc	16	16	60
Cation Exchange Capacity (milliequivalents/100 g soil)	23	22	26

All concentrations in mg/kg unless otherwise noted
pH is reported as $-\log[H^+]$
"Hi" indicates potential for iron chlorosis or injury from pesticide carryover

Performance Data

The following conditions were monitored during the demonstration:

- Soil PAH, PCB, DRO and agricultural (Row Crop Test) concentrations prior to planting the first season, also known as baseline (T=0), prior to planting the second growing season (T=1), and after the second growing season (T=2).
- Plant assessments were completed during the second growing season to evaluate percent cover, shoot biomass, and root parameters.
- Tensiometers were installed during the second growing season to measure soil moisture
- Weather data was gathered from the National Oceanic and Atmospheric Administration (NOAA) station at nearby Mitchell Airfield in Milwaukee.

Baseline samples were collected during June 2001 shortly before initial planting. A second set of samples was collected in May 2002 before the start of the second growing season, and a third and final collection occurred in September 2002. Baseline results indicate that preparation of the soil prior to placement was successful in adequately distributing the pollutants amongst the 16 treatment cells. Analyte concentrations in individual cells ranged from 77 to 161 mg/kg PAHs, 2.0 to 3.6 mg/kg PCBs and 24 to 440 mg/kg DRO.

After the establishment of the test plots, management routines were not set up appropriately, leading to less-than-optimum irrigation schedules and inadequate weeding in the willow and plant suppression plots. Corn did not germinate in the initial planting and was replanted by the ERDC in August, 2001. However, irrigation and maintenance schedules were better coordinated during the 2002 growing season, and plant vitality was much improved, as seen in Figure 5.

PAHs. In comparison with WDNR NR 538 Category 1 standards, corn, natural vegetation, and willow produced 90% UCL PAH concentrations at or below numerical standards with 7 of 16 compounds; plant suppression, 8 of 16 compounds (Table 3). Against less stringent Category 2 standards, corn, natural vegetation, and willow produced 90% UCL PAH concentrations at or below numerical standards with 8 of 16 compounds; plant suppression, 11 of 16 compounds (Table 4). A similar evaluation using mean T=0 data, however, shows that most of the results described above had already been achieved (data not shown).

Figure 5. First corn crop during 2002 growing season

PCBs. None of the treatments produced a final mean concentration of total PCBs below this standard. This holds true for both aroclor and congener-based results (Table 5).

DRO. None of the treatments produced a final mean concentration of DRO below the applicable standard (Table 5). A number of possible explanations for the increase in DRO over the course of the field demonstration have been explored, ranging from uniformly higher spike recoveries and obscured chromatographic peak areas to natural variability and even biogenesis of similar molecular weight organic compounds. None of these possibilities provides a complete explanation; however, the occurrence underscores some of the inherent difficulty in using analytical techniques based upon fingerprint identification and quantification.

Vegetation growth was assessed two times during 2002 in July and September. The plant assessments showed vegetation treatments were successfully established. However, the shallow depth of the soil in the treatment system (much less than the 30 cm design criterion) probably limited plant growth and root development. The soil depth likely restricted plant nutrient availability and resulted in increased irrigation needs more than would probably be required in a system with a deeper soil profile.

The only plots that had plant growth for most of the first growing season were the natural vegetation and the willow plots (which had significant weed growth). Comparing the total PAH data for T=0 and T=1 (see Table 6), concentration reduction ranked by treatment was natural vegetation>willow>corn. Natural vegetation and willow plots had the longest period of exposure to plant roots during the 2001 growing season, which is possibly the reason for the greater reduction in PAHs. Reductions of PAH concentrations in 2002 were ranked natural vegetation>corn>willow, which is consistent with total root mass natural vegetation>corn>willow determined by the plant assessments (data not shown). With better weed control in the willow plots during the 2002 growing season, less root mass was produced and PAH reduction ceased.

Technology Status

The USACE in partnership with the Milwaukee Port Authority is exploring an extensive range of beneficial use options for the harbor dredgings, from building materials to road fill to landscaping soil. Assisting the search is the University of Wisconsin-Milwaukee Center for By-Products Utilization (CBU). The CBU is working on combining dredged materials with wood ash and other materials to make fertilizer and topsoil that could be used by nurseries, Christmas tree farms, and forests planted by paper mills.

For the USACE, this demonstration is part of a continuum of projects under its Dredging Operations and Environmental Research (DOER) program. A compendium of DOER efforts examining dredged material characterization, treatment and beneficial use options is available in the form of Technical Notes and can be downloaded in PDF format at the following address: http://www.wes.army.mil/el/dots/doer/technote.html

Sources of Further Information

An Innovative Technology Evaluation Report (ITER) of this study is currently being prepared and should be available in Fall 2003.

Contact Information

EPA Project Manager:
Steve Rock
U.S. Environmental Protection Agency
5995 Center Hill Avenue
Cincinnati, OH 45224
Tel: 513-569-7149
rock.steven@epa.gov

USACE Project Managers:
Richard Price
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199
Tel: 601-634-3636
Richard.A.Price@erdc.usace.army.mil

David Bowman
U.S. Army Corps of Engineers
Detroit District
477 Michigan Avenue
P.O. Box 1027
Detroit, MI 48231-1027
Tel: 313-226-2223
David.W.Bowman@lre02.usace.army.mil

Table 3. PAH Treatment Results vs. NR 538 Category 1 Standards.

PAH Compounds	Standard	Treatment Means (mg/kg)				90% UCL (mg/kg)			
	(mg/kg)	Corn	Natural	Supprn	Willow	Corn	Natural	Supprn	Willow
Acenaphthene	900	0.7	0.74	0.54	0.76	0.8	0.88	0.6	0.9
Acenaphthylene	8.8	0.72	0.78	0.63	0.69	0.91	0.96	0.75	0.82
Anthracene	5000	1.9	2.0	1.6	2.0	2.3	2.4	1.7	2.4
Benzo(a)anthracene	0.088	6.5	6.8	5.8	6.8	7.4	7.9	6	7.4
Benzo(a)pyrene	0.008	7.9	8.8	7.0	8.4	9.1	10	7.4	9.4
Benzo(b)fluoranthene	0.088	11	13	10	12	13	16	11	14
Benzo(g,h,i)perylene	0.88	4.2	3.0	3.7	3.5	5.3	3.5	4.9	4.8
Benzo(k)fluoranthene	0.88	7.5	8.7	5.4	8.5	9.7	9.7	5.7	11
Chrysene	8.8	8.4	8.8	7.5	8.7	9.6	10	8	9.4
Dibenzo(a,h)anthracene	0.0088	1.3	1.0	1.2	1.2	1.4	1.2	1.5	1.5
Fluoranthene	600	17	19	15	17	19	21	1.7	20
Fluorene	600	0.75	0.86	0.64	0.83	0.87	1.1	0.7	0.95
Indeno(1,2,3-cd)pyrene	0.088	3.9	3.2	3.7	3.5	4.4	3.8	4.7	4.5
Naphthalene	600	2	2.2	1.5	1.5	2.6	2.9	1.7	1.7
Phenanthrene	0.88	8.8	10	7.5	9.2	10	11	8.1	10
Pyrene	500	12	13	10	13	14	15	11	14

Note: Shaded results are at or below standard

Table 4. PAH Treatment Results vs. NR 538 Category 2 Standards.

PAH Compounds	Standard	Treatment Means (mg/kg)				90% UCL (mg/kg)			
	(mg/kg)	Corn	Natural	Supprn	Willow	Corn	Natural	Supprn	Willow
Acenaphthene	9000	0.7	0.74	0.54	0.76	0.8	0.88	0.6	0.9
Acenaphthylene	88	0.72	0.78	0.63	0.69	0.91	0.96	0.75	0.82
Anthracene	50000	1.9	2.0	1.6	2.0	2.3	2.4	1.7	2.4
Benzo(a)anthracene	0.88	6.5	6.8	5.8	6.8	7.4	7.9	6	7.4
Benzo(a)pyrene	0.08	7.9	8.8	7.0	8.4	9.1	10	7.4	9.4
Benzo(b)fluoranthene	0.88	11	13	10	12	13	16	11	14
Benzo(g,h,i)perylene	8.8	4.2	3.0	3.7	3.5	5.3	3.5	4.9	4.8
Benzo(k)fluoranthene	8.8	7.5	8.7	5.4	8.5	9.7	9.7	5.7	11
Chrysene	88	8.4	8.8	7.5	8.7	9.6	10	8	9.4
Dibenzo(a,h)anthracene	0.088	1.3	1.0	1.2	1.2	1.4	1.2	1.5	1.5
Fluoranthene	6000	17	19	15	17	19	21	1.7	20
Fluorene	6000	0.75	0.86	0.64	0.83	0.87	1.1	0.7	0.95
Indeno(1,2,3-cd)pyrene	0.88	3.9	3.2	3.7	3.5	4.4	3.8	4.7	4.5
Naphthalene	6000	2	2.2	1.5	1.5	2.6	2.9	1.7	1.7
Phenanthrene	8.8	8.8	10	7.5	9.2	10	11	8.1	10
Pyrene	5000	12	13	10	13	14	15	11	14

Note: Shaded results are at or below standard

Table 5. PCB and DRO Treatment Results vs. Project Standards.

Analytes	Standard	Treatment Means* (mg/kg)				90% UCL (mg/kg)			
	(mg/kg)	Corn	Natural	Supprn	Willow	Corn	Natural	Supprn	Willow
PCB Aroclors	<1	4.4	4.8	4.2	4.4	5	5.6	4.5	5
PCB Congeners	<1	4.1	3.9	3.8	3.6	NA	NA	NA	NA
DRO	100	150	230	110	160	180	280	140	200

Notes:
*PCB Congener results are for a single analysis
NA Not applicable

Table 4-6. Comparison Between T=0, 1 & 2 Analyte Data.

	Polynuclear Aromatic Hydrocarbons (mg/kg)											
	Corn			**Natural Vegetation**			**Plant Suppression**			**Willow**		
PAH Compounds	T=0	T=1	T=2	T=0	T=1	T=2	T=0	T=1	T=2	T=0	T=1	T=2
Acenaphthene	0.9	0.85	0.7	1.3	1.1	0.74	0.65	0.96	0.54	0.94	0.86	0.76
Acenaphthylene	0.73	0.96	0.72	0.72	1.1	0.78	0.7	0.88	0.63	0.76	0.96	0.69
Anthracene	2.6	1.8	1.9	4	2.4	2	1.9	2.2	1.6	2.6	1.8	2
Benzo(a)anthracene	7.4	7.2	6.5	10	7.9	6.8	6.6	7.6	5.8	8.6	7	6.8
Benzo(a)pyrene	9	9.2	7.9	12	11	8.8	8.2	9.5	7	10	9.2	8.4
Benzo(b)fluoranthene	14	15	11	18	18	13	13	15	10	16	15	12
Benzo(g,h,i)perylene	3.4	3	4.2	3.6	3.3	3	3	3.9	3.7	4.1	2.8	3.5
Benzo(k)fluoranthene	5.6	5.7	7.5	7.6	7	8.7	5.7	6.2	5.4	5.6	6.8	8.5
Chrysene	9.2	8.5	8.4	12	9.5	8.8	8.1	8.9	7.5	11	8.3	8.7
Dibenzo(a,h)anthracene	1.1	1	1.3	1.2	1.1	1	1	1.2	1.2	1.4	0.91	1.2
Fluoranthene	16	18	17	22	20	19	14	19	15	18	18	17
Fluorene	1.1	0.98	0.75	1.7	1.3	0.86	0.74	1.1	0.64	1.1	0.98	0.83
Indeno(1,2,3-cd)pyrene	3.7	3.2	3.9	4	3.6	3.2	3.2	4.1	3.7	4.4	3.2	3.5
Naphthalene	1.7	1.7	2	2.2	1.7	2.2	1.6	1.9	1.5	2.3	1.6	1.5
Phenanthrene	10	8.6	8.8	15	11	10	8.2	10	7.5	12	8.7	9.2
Pyrene	14	12	12	18	14	13	12	13	10	15	12	13
Total PAHs	100	98	94	130	110	100	89	110	74	110	98	97
	PCB Aroclors (mg/kg)											
	Corn			**Natural Vegetation**			**Plant Suppression**			**Willow**		
PCB Aroclors	T=0	T=1	T=2	T=0	T=1	T=2	T=0	T=1	T=2	T=0	T=1	T=2
1242	1.1	1.5	1.4	0.94	1.6	1.6	0.96	1.6	1.4	0.94	1.6	1.5
1254	1.3	1.9	2	1.2	2.1	2.2	1.2	1.9	1.9	1.2	2	2
1260	0.4	0.75	0.93	0.36	1.1	1.1	0.37	0.78	0.88	0.41	0.87	0.94
Total Aroclors	2.8	4.2	4.4	2.5	4.9	4.8	2.5	4.3	4.2	2.5	4.5	4.4
	PCB Congeners (mg/kg)											
	Corn			**Natural Vegetation**			**Plant Suppression**			**Willow**		
	T=0	T=1	T=2	T=0	T=1	T=2	T=0	T=1	T=2	T=0	T=1	T=2
Total Congeners	4.2	3.2	4.1	3.7	4.6	3.9	4.7	3.7	3.8	3.9	3.4	3.6
	Diesel Range Organics (mg/kg)											
	Corn			**Natural Vegetation**			**Plant Suppression**			**Willow**		
	T=0	T=1	T=2	T=0	T=1	T=2	T=0	T=1	T=2	T=0	T=1	T=2
DRO	64	140	150	140	250	230	59	220	110	91	280	160

Note: Results rounded to two significant figures

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Research Laboratory
Cincinnati, OH 45268

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