ENHANCED BIOREMEDIATION OF WOOD TREATMENT SOILS CONTAINING CHLORINATED PHENOLS AND PAHs

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Summary

The effectiveness of Daramend™ bioremediation for remediating industrial wood treatment soils was evaluated at pilot-scale and full-scale. The demonstrations were conducted at the Domtar Wood Preserving site in Trenton, Ontario. Soils at the site contained chlorinated phenols, polyaromatic hydrocarbons (PAH) and petroleum hydrocarbons. The bioremediation technology was optimized for the site conditions during bench-scale treatability investigations. Results from the bench-scale and pilot-scale demonstrations were very positive, with final residuals of less than CCME (1991) guidelines being achieved. Toxicity tests performed on the soil treated at pilot-scale indicated that the toxicity noted previously had been completed removed. The full-scale demonstration, which includes bioremediation of approximately 4,500 m^3 (1,500 m^3 ex-situ and 3,000 m^3 in-situ) of soil, was initiated in early summer of 1993.

The ex-situ portion of the full-scale demonstration is being audited by the USEPA under the SITE program.

Acknowledgment

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1. Introduction

A full scale demonstration of Daramend bioremediation for soil containing chlorinated phenols, PAHs and petroleum hydrocarbons is being performed at the Domtar Wood Preserving site in Ontario. The soil contains chlorinated phenols, PAHs and total petroleum hydrocarbons at concentrations of up to 700, 1400 and 6300 mg/kg respectively. Full-scale bioremediation at this site employs the same Daramend protocols and organic amendment treatments as were applied during the pilot-scale demonstration. During an earlier pilot-scale demonstration at the same site, concentrations of the target organics were reduced to below the Canadian clean-up guidelines (CCME, 1991) for industrial soils.

Extensive laboratory studies with a wide range of soils containing wood treatment chemicals have proven the Daramend process effective in enhancing target compound degradation rates. Soils containing up to 2170 mg/kg PCP were amenable to Daramend treatment. Previous studies in the United States indicated that soils containing more than 300-400 mg PCP/kg may be too toxic for direct bioremediation, requiring other preliminary treatments such as soil washing (Crawford and Mohn, 1985). With Daramend, residual PCP concentrations less than 1 mg/kg PCP are frequently obtained. Conversely, persistent residual concentrations of 10-50 mg/kg are often reported in the literature (Crawford and Mohn, 1985; Edgehill et al., 1983).

The objective of this paper is to outline the technology used to remediate the soil at the Domtar Wood Preserving facility. At the site in question, wood treatment utilized creosote exclusively from the early 1900's to mid 1960's. Since then both creosote and pentachlorophenol (PCP) were used until the treatment facility was shut down in 1992. The site is presently used to store lumber which has been treated elsewhere.

On-site storage of treated wood had led to the deposition of chlorophenols, PAHs and petroleum hydrocarbons.

2. Methodology

Daramend bioremediation is characterized by the use of solid-phase organic amendments which have soil specific properties including particle size distribution, nutrient profile, and nutrient release kinetics. The process also utilizes low intensity tillage of the soil and strict maintenance of soil water content. The organic soil amendments increase the rate of bioremediation by improving environmental conditions (nutrient status, biologically available water, surfaces for microbial adhesion and interfacial contact between the target compounds and microorganisms that degrade them) for microbial growth. The ability to cost-effectively increase the activity of PCP, PAH, and hydrocarbon-degrading bacteria in wood treatment soils renders Daramend bioremediation applicable to a great number of wood treatment sites.

Pilot and Full Scale Ex-Situ Treatment Areas:

The confined treatment areas for ex-situ treatment of soils were constructed using high density polyethylene liners, geotextile pads and sand. Soil was deposited on liners to a depth of 0.6 m. Steel/polyethylene structures were constructed to cover the treatment areas to provide positive control of the soil moisture content while eliminating the potential for leachate generation. A schematic of the ex-situ area constructed for the full scale demonstration is presented in Figure 1.

The soil to be treated was transported to the treatment area and homogenized by tilling with a power take-off driven rotary tiller. Tillage reduces variation in the soil

physical and chemical properties (e.g. small regions of very high target compound concentration which may inhibit their biodegradation) and uniformly distributes organic amendments throughout the soil matrix. The soil was treated to a depth of 0.6 m.

During the remediation process, soil moisture content was maintained within a specific range, below the material's water holding capacity, to facilitate rapid growth of a large and active microbial population. Excess moisture can limit diffusion of oxygen through the soil matrix to microbially active microsites where biodegradation occurs. Conversely if soil moisture falls below the optimum range, biodegradation can be inhibited by an inadequate supply of biologically available water. Optimal soil moisture contents were determined during bench-scale treatability investigations.

The pilot-scale demonstration involved the treatment of over 100 tonnes of excavated soil and was performed over the course of two years. Initial target compound concentrations in the pilot-scale demonstrations were 702 mg/kg for chlorophenols and approximately 1400 mg/kg for PAHs. Total petroleum hydrocarbons ranged from 6900 - 7100 mg/kg. A 7 m x 38 m confined treatment facility was constructed to facilitate treatment of approximately 100 tonnes of excavated soil. Soil was deposited on the liner to a depth of 0.6 m and homogenized by tillage. A 1 m x 6 m buffer zone was established at one end of the plot to serve as a control area.

The treatment area was divided into eighteen 2 m x 6 m sampling zones. Each zone contained twelve 1 m x 1 m pedons which were sampled with the split spoon corer. The 12 samples from each zone were composited, homogenized and sub-sampled for analyses. A total of 18 composite samples were collected from the treatment area. An additional 6 samples were taken from each of the six pedons in the control zone.

The full scale demonstration was initiated in the summer of 1993. Two ex-situ areas containing 1,500 tonnes of contaminated soil were constructed. One of the treatment areas also includes the area being monitored by the USEPA SITE program. Initial concentrations of chlorinated phenols in the full scale ex-situ demonstration averaged 127 mg/kg.

Organic Amendments, Tillage and Irrigation:

The soils were treated with the most effective amendment(s) as determined by the treatability investigations. The water holding capacities (WHC) of the amended soils were determined and drip-irrigation systems were utilized to maintain soil water contents near the optimum percentage WHC. The drip irrigation system provides uniform distribution of water to the surface of the plots.

Soils were tilled approximately once every two weeks to increase diffusion of oxygen to microsites and to re-distribute water in treatment zones. Irrigation requirements were determined by weekly monitoring of soil moisture content, using gravimetric

techniques, at two depths: 0-20 and 20-45 cm. The first depth is the zone where most of the flux occurs due to microbial utilization of the antecedent moisture, evaporation, and downward migration due to gravity in the soil/sediment macropores. Samples from the lower depth can reveal accumulation of moisture due to migration of water from the upper portion of the treatment zone. Taken together the two values allowed effective characterization of the moisture status of the soil.

3. Results and Discussion

Pilot-scale Ex-Situ Treatment Area

Data on biodegradation of PCP during Daramend treatment is presented in Figure 2.

Rapid reductions in PCP concentrations were observed in the treated soil. The mean concentration of PCP was reduced by 99.2% from an initial concentration of 662 mg/kg to 5 mg/kg in the treated soil. These data compare to a 32% reduction in the mean PCP concentration in the control plot (from 622 mg/kg to 423 mg/kg).

The residual PAH concentrations in the soil after application of the Daramend process are given in Figures 3 through 5.

Rapid reductions in PAH concentrations were observed in Daramend treated soil when compared to the control. Total PAH concentration was reduced by 98.2% from an initial concentration of 1900 mg/kg to 35 mg/kg. Concentrations of PAHs in the control area were not reduced during the same time period.

Degradation rates of the more recalcitrant PAHs were higher in the treated soil than in the control plot. For example, the concentration of pyrene was reduced by 99.2% in the treated soil, while concentrations in the control plot remained relatively unchanged during the same time period.

Full Scale Ex-Situ Treatment Area

The full scale ex-situ treatment areas have been fully constructed. EPA SITE auditors have completed the baseline and time zero testing for the demonstration. The first sampling is scheduled to be performed the week of October 25, 1993.

Full Scale In-Situ Treatment Area

The in-situ treatment area has been fully treated. The first sampling time is scheduled to take place the week of October 25, 1993.

4. Conclusions

Performance data from pilot-scale demonstration of Daramend bioremediation indicate remediation of soils with high levels of chlorinated phenols and polycyclic aromatic hydrocarbons is practical. The attainment of CCME guidelines was also confirmed. On the basis of these positive results, a full scale demonstration of the process was initiated in the summer of 1993. The USEPA has indicated an interest in the technology by including it in their SITE program.

5. Literature

Crawford, R.L. and Mohn, W.W. 1985. Microbiological removal of pentachlorophenol from soil using a Flavobacterium. Enzyme Microb. Technol. 7:617-620.

Edgehill, R.U. and Finn, R.K. 1983. Microbial treatment of soil to remove pentachlorophenol. Appl. Environ. Microbiol. 45:1122-1125.

Canadian Council of Ministers of the Environment. September 1991. Interim Quality Criteria for Contaminated Sites. CCME EPC-CS34, Winnipeg, Manitoba.

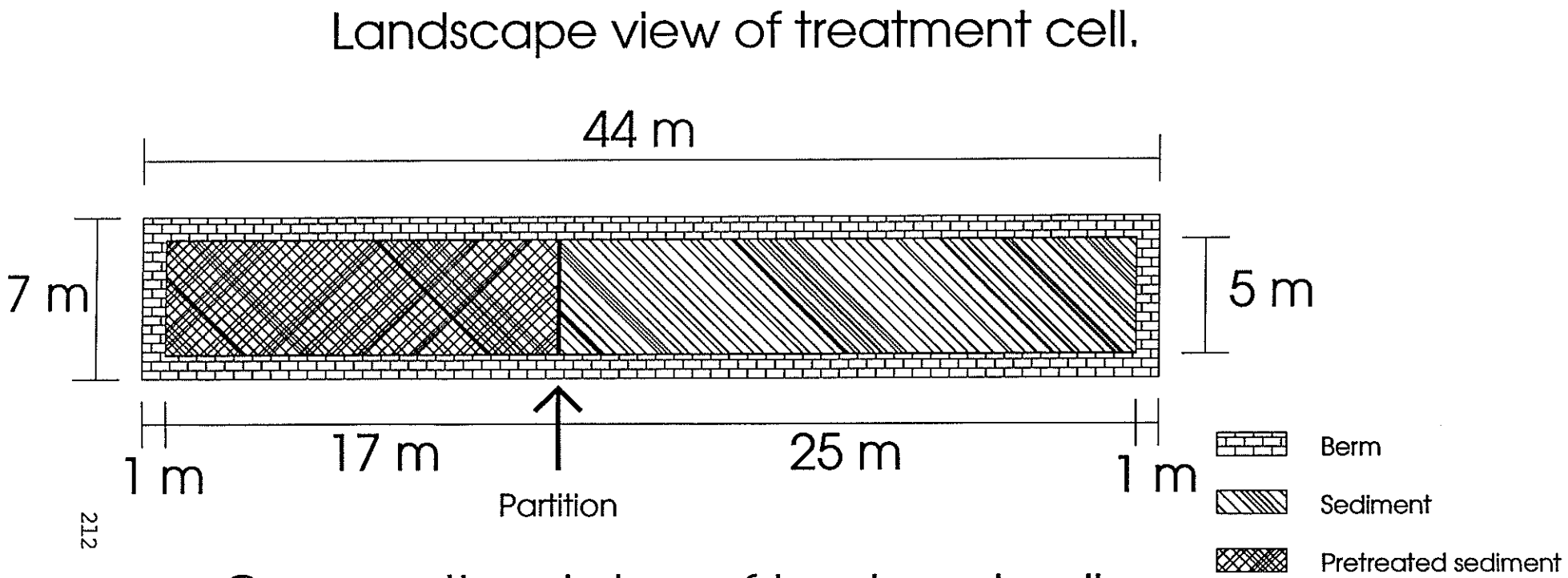

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Figure 1: Schematic of Full-Scale Ex-situ Treatment Area

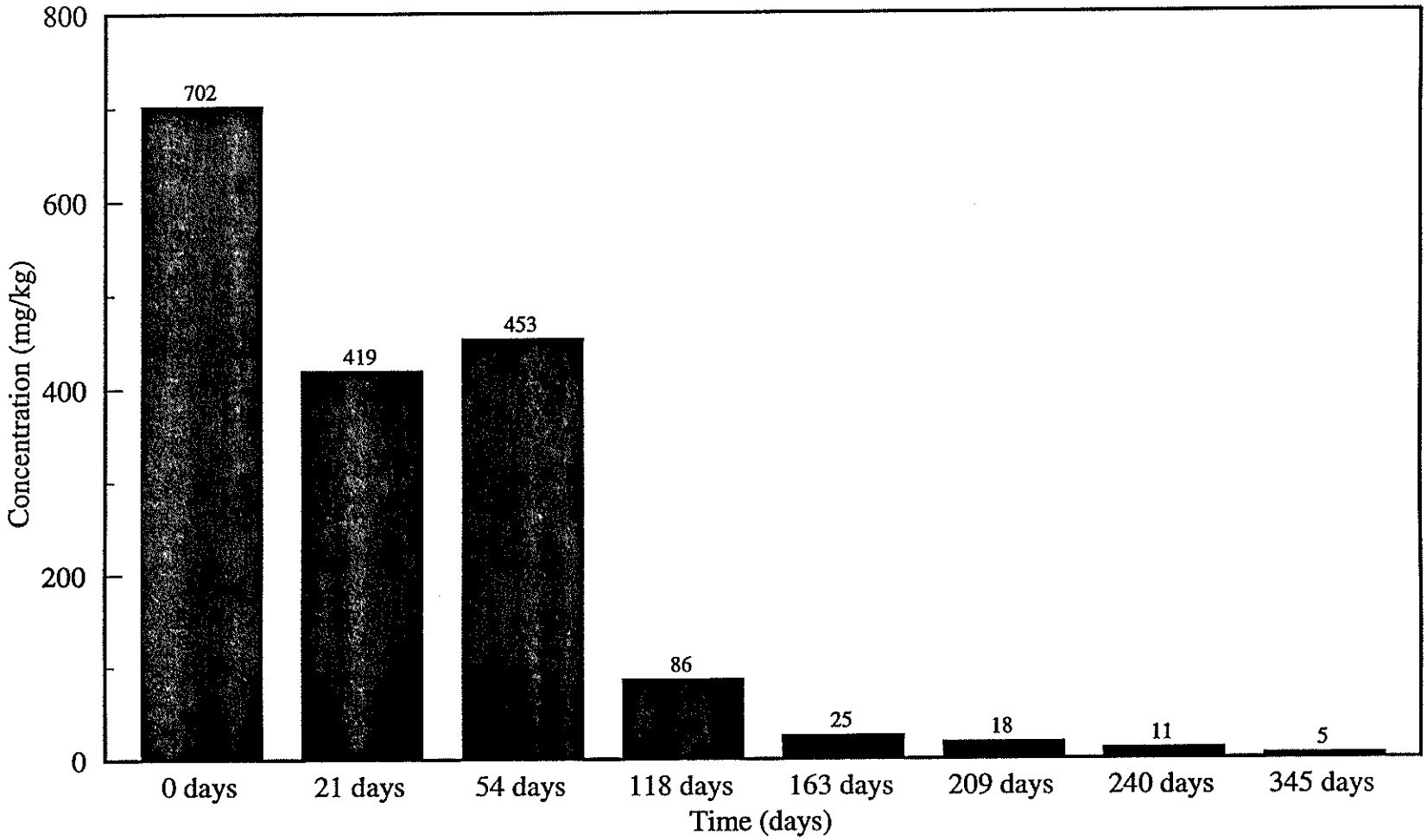

Figure 2. Residual chlorophenol concentrations in excavated soil treated on-site during pilot-scale demonstration of Daramend bioremediation.

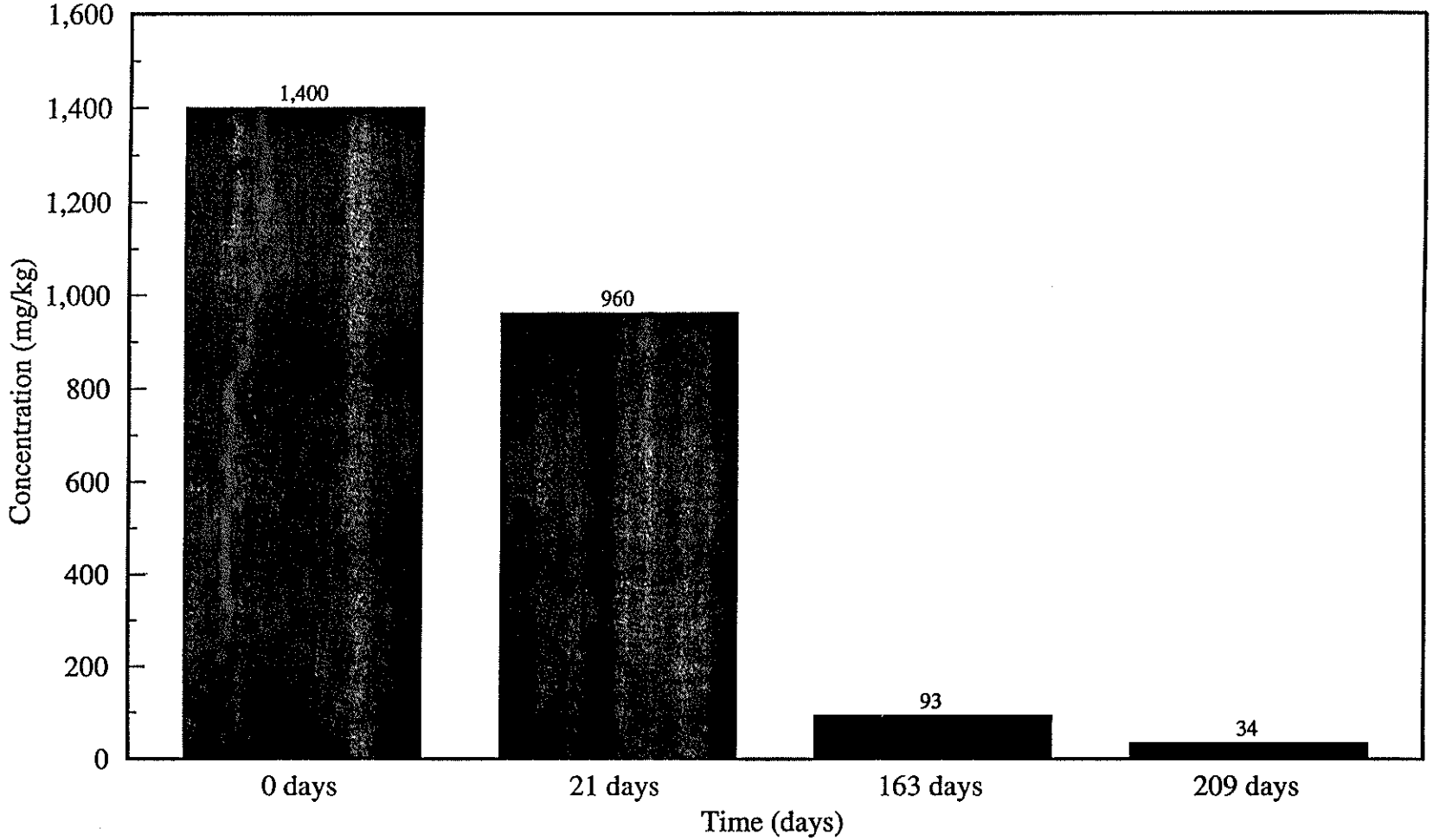

Figure 3. Residual total PAH concentrations in excavated soil treated on-site during pilot-scale demonstration of Daramend bioremediation.

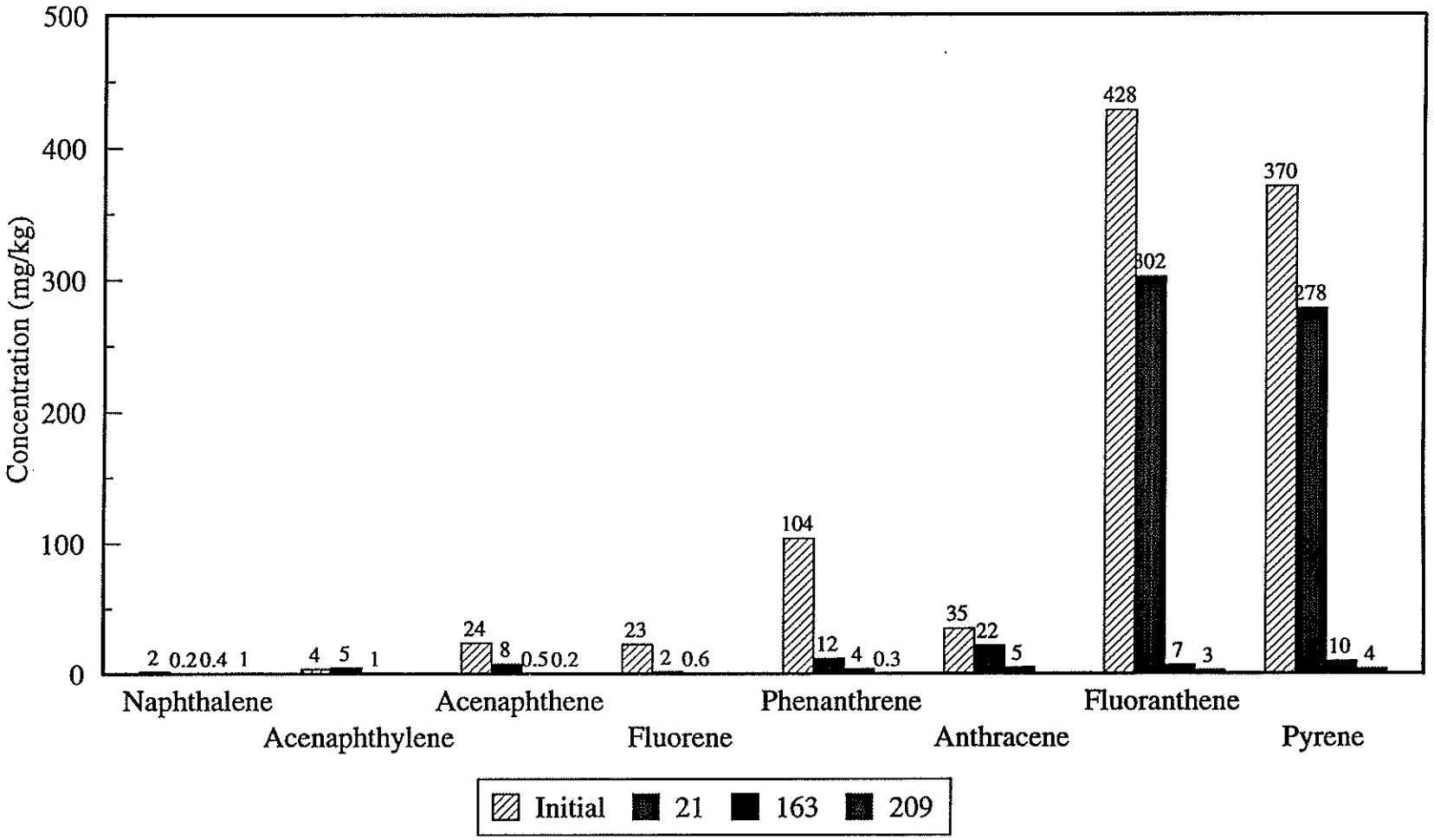

Figure 4. Residual concentrations of low molecular weight PAHs in excavated soil treated on-site during pilot-scale demonstration of Daramend bioremediation.

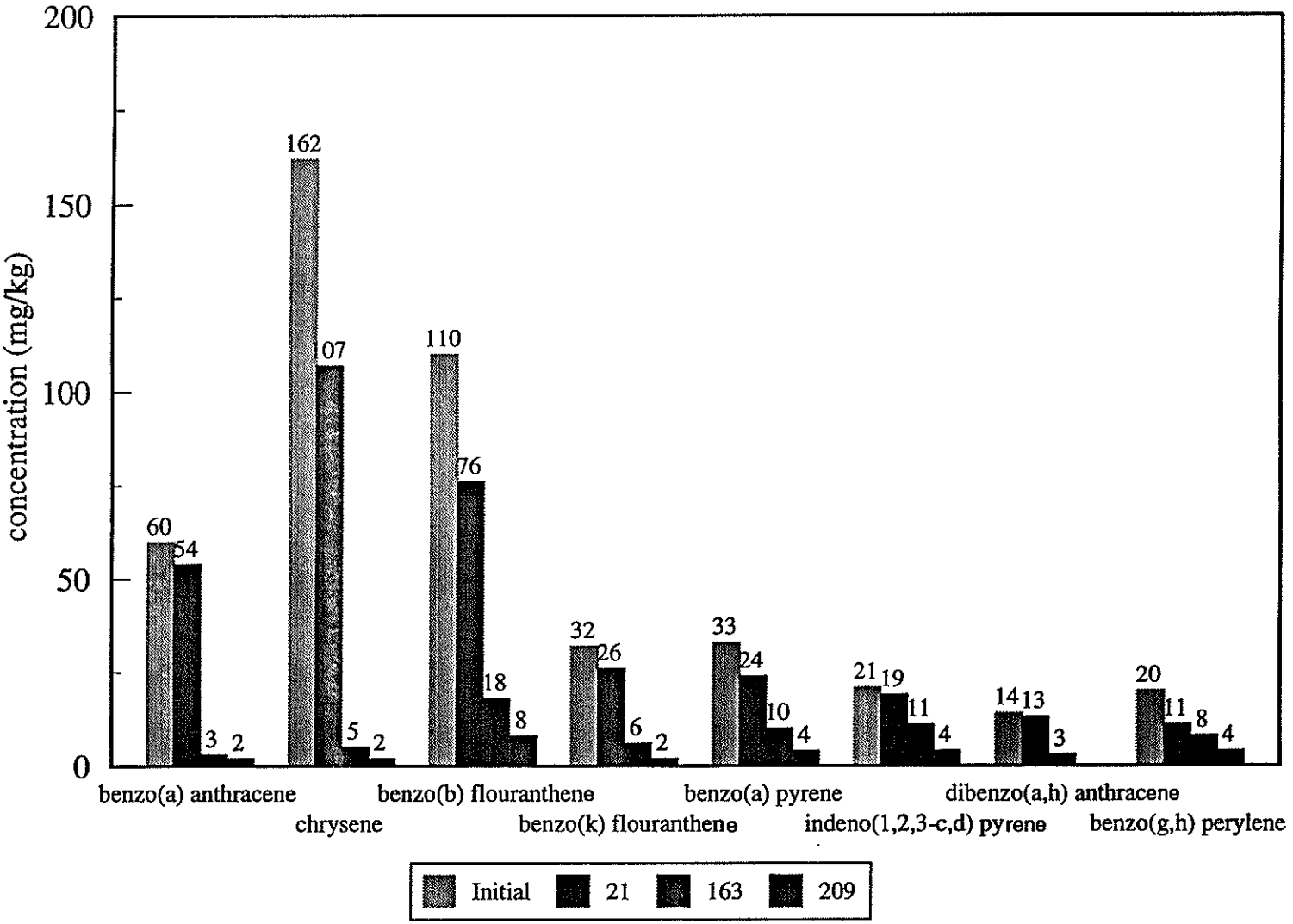

Figure 5. Residual concentrations of higher molecular weight PAHs in excavated soil treated on-site during pilot-scale demonstration of Daramend bioremediation.