BIOREMEDIATION DEMONSTRATION UNIT AT WEED, CALIFORNIA

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Introduction

The J.H. Baxter/International Paper/Roseburg Superfund site is in the city of Weed, located in northern California. The site is underlain by coalescent fans of pyroclastic, mudflow, glacial, and fluvial deposits from the northwestern flank of Mount Shasta and Mount Shastina. The shallow water table, about 5-10 feet below the surface, fluctuates with rainfall and snow melts. The site is at an elevation of 3,400 feet above sea level. The average 27 inches of precipitation occurs mostly during the winter as rain or snow. Summer daytime temperatures average 90°F, and winter daytime temperatures average 22°F.

The site has been an active wood treating plant since 1936. Waterborne and oilborne preservatives, as well as flame retardants, have been used at the site. Waterborne preservatives and flame retardants used include Tanalith, Minalith, FCAP, ACZA, and Pyresote. The oilborne preservatives, creosote and pentachlorophenol, have been used at the site. Creosote has been used from the beginning, but pentachlorophenol was used only from the 1950's to 1982.

The Weed site has several areas where the soil is contaminated with the various wood preservatives. Contaminated areas include two ponds, a spray field, and the areas surrounding a 500,000 gallon storage tank, a retort, and the drip pads. Inorganic contaminants are widespread on the site but apparently are largely confined to the soil surface. The organic contamination is less widespread on the site but is often found deep in the soil.

As part of a comprehensive site remediation plan, land treatment of the pentachlorophenol and creosote contaminated soils was considered as a treatment alternative. This study was conducted to determine the feasibility of using land treatment on these soils. The study consists of three phases: Phase 1: laboratory studies of microbial degradation of pentachlorophenol and creosote in contaminated soils; Phase 2: a field demonstration study; and Phase 3: a full-scale land treatment demonstration facility. Phases 1 and 2 have been completed and the results are reported here.

Methods

Phase 1. The first phase of this study encompassed the following tasks:

Determining the existing levels of organic and inorganic preservative contamination in the soils considered for land treatment;

Determining the levels of carbon, nitrogen, and phosphorus in the soil to find if they were sufficient for high microbial growth rates;

Determining the rate of breakdown of creosote components [polycyclic aromatic hydrocarbons (PAHs)] and pentachlorophenol (PCP) in creosote and pentachlorophenol contaminated soil;

Determining if the existing bacteria population is sufficient or if additional bacteria are necessary for adequate degradation;

Determining if high metal concentrations might inhibit microbiological degradation of creosote and pentachlorophenol in site soils.

The six site areas noted below were chosen for detailed study on the basis of data from previous site studies.

Roseburg Excavated Pond
Baxter Site Retort Area
500,000-Gallon Tank
Baxter Site Sump
Baxter Site Drip Pads
Baxter Site Spray Field

Soil subsamples for determining existing contamination levels were collected from six locations in each area and composited. Soil samples were shipped to the Mississippi Forest Products Laboratory at Mississippi State University for analysis.

Degradation rates of creosote and PCP in the soil were measured by use of a modification of the proposed treatability-screening procedure described in the EPA publication Permit Guidance Manual on Hazardous Waste Land Treatment Demonstrations. The procedure involved the following steps:

For biological studies, the soils from the individual areas were divided into two groups consisting of: 1) soils which contained over 100 ppm of arsenic, chromium, copper, or zinc; and 2) soils which had metal concentrations less than 100 ppm (according to data previously gathered by the EPA). Samples that contained over 100 ppm of any of the metals were tested at full strength and at dilutions of 1/2 and 1/4 with uncontaminated soil from a control area. Soils with metal concentrations below 100 ppm were tested without dilution.

Test units were set up in triplicate for soil from each site. Each unit consisted of a brown glass container (to minimize UV degradation) containing 800 g (dry weight) of thoroughly mixed soil.

Organic and inorganic nutrients were added. In order to maximize the rate of biological degradation, the moisture content was adjusted to 70 percent water holding capacity.

The test units were incubated at $22^{\circ} \pm 2^{\circ}C$ for the duration of the test.

The moisture content in each unit was adjusted weekly to 70 percent of the soil water holding capacity, and the soil was aerated by hand mixing.

At 0, 2, 4, 8, and 12 weeks, soil samples (80.0 g) were removed from each test unit and analyzed for creosote/ pentachlorophenol acclimated and total bacteria populations, seventeen polynuclear aromatic hydrocarbons (PAHs), pentachlorophenol (PCP), and tetrachlorophenol (TeCP).

Phase 2. In Phase 2, the tank soil and the excavated pond soil were treated in six aboveground closed system test cells constructed on-site. The objectives

of the Phase 2 site demonstration studies were as follows:

Determine the rate of transformation under field conditions.

Determine migration of hazardous components during active bioremediation.

Test cells were steel boxes constructed as shown in Figure 1. The boxes, 6 feet wide by 12 feet long by 5 feet deep, were lined with a 60-mil synthetic liner. To limit rain infiltration and to minimize soil loss by wind erosion, a clear plastic canopy was used to cover each box. Each box was sloped 0.5 to 1.0% and had a valve located 4 inches from the bottom at the lower end of the box.

A 1-foot layer of sand was placed directly over the synthetic liner in each box, and a 3-foot layer of clean control soil was placed on top of the sand layer. The clean soil was added in 1-foot lifts and lightly tamped to reduce settling of the soil in the cells. The layer of sand at the bottom of each box and the layer of "clean soil" did not contain pentachlorophenol or polycyclic aromatic hydrocarbons. However, these layers did contain part-per-million levels of copper, chromium, zinc, and arsenic. The contaminated soils to be treated in this study were placed on top of the clean soil layer. Contaminated soils from the tank area and the Roseburg Excavated Pond area were chosen for use in the field study because they had high levels of organic contaminants and because these soils were representative of a major portion of the contaminated soil at the site. The boxes were loaded according to the schedule shown in Table 1.

The soil in each box was tilled twice weekly. Approximately every three days, the test cells were irrigated to maintain soil moisture at 30 to 70 percent of field capacity. Drainage water accumulated in the sand layer in each box was removed at monthly intervals and recycled or disposed.

During spring and summer, the soil and drainage water in each box was sampled at approximately monthly intervals. The soil sampling points in each box were located on a sampling grid of 6 x 6 inch squares. A random number generator was used to identify 6 grid points within each box. To minimize edge effects, no samples were taken in a one-foot buffer zone around the periphery of each box. At each chosen grid point, subsamples were taken at the surface, 12 inches deep, and 24 inches deep. The subsamples at each depth for individual boxes were combined. Soil samples were analyzed for creosote/pentachlorophenol acclimated and total bacteria populations, seventeen polynuclear aromatic hydrocarbons (PAHs), pentachlorophenol (PCP),

tetrachlorophenol (TeCP), and octachlorodibenzo-p-dioxin. Drainage water samples were tested for seventeen PAHs, PCP, and TeCP.

Results

Phase 1. The levels of nitrogen, phosphorus, and organic carbon in the different soils are listed in Table 2. All levels appeared to be adequate for biodegradation with the exception of the Roseburg Excavated Pond soil which is low in organic carbon. The carbon/nitrogen ratios of the retort and tank soils were slightly higher than desirable due to the very high organic levels in the soils in these areas. Results of the metal analyses (copper, chromium, zinc, and arsenic) for the six soils are shown in Table 3. These concentrations did not appear to noticeably inhibit breakdown rates in the laboratory studies.

Initial concentrations of PCP, TeCP, and total PAHs in the soils are shown by the undiluted soil values in the Day 0 column of Tables 4 and 5. PCP was found only in the tank, retort, and sump areas. TeCP was found only in the tank area. PAHs were found in all soils except the spray field soils. The tank and retort area soils had the highest starting PAH levels in this study. The excavated pond and sump soils showed moderate PAH levels. The drip pad soil had relatively low starting levels of PAHs, and the spray field soil had no PAHs.

Table 4 shows the changes in concentration of PCP and TeCP in samples taken through the course of the 84-day laboratory degradation study. Table 5 shows the changes in concentration of total PAHs during the study. Table 6 shows the estimated first order rate constants and half-lives for PCP and total PAHs. All classes of PAHs exhibited good breakdown rates in the laboratory. The low levels in the drip pad soil were quickly degraded, and at Day 14 of the study no PAHs were detected. No further analyses were conducted on the spray field and drip pad soils. The tank soil had good breakdown rates of both PAHs and PCP with an average PAH half-life of about 70 days and an average PCP half-life of about 103 days. The only exception was the undiluted tank soil with added inorganic fertilizer which had a very long half-life for total PAHs. This may be caused by a high chloride concentration in the soil due to dechlorination of pentachlorophenol. The acclimated microbe populations were slow to increase in this soil.

The retort soil, with much lower initial levels of PCP and PAHs than the tank soil, had an average half-life of 55 days for total PAHs and 76 days for PCP. The one-quarter dilution of the retort soil seemed to degrade PAHs very slowly. The sump soil had very good breakdown rates of PCP with an average half-life of 36 days. Total PAH breakdown in the sump soil was a little slower than in the other soils with an average half-life of 106 days. The excavated pond had good total PAH breakdown rates with an average half-life of 43 days.

In all the soils except the 1/4 dilution of the Retort soil (Retort 1/4), the microbial populations developed readily and good population levels (5-10 million counts/gram soil) were maintained (data not shown). Acclimated bacteria levels were at moderate to high levels. Fungi populations (considered important in PCP breakdown) were particularly high, indicating that good PCP breakdown rates could be expected.

Phase 2. The percentage reductions of PAHs, PCP, TeCP, and OCDD based on the initial value and final values are given in Table 7. These values are based on a single loading. In the cases where the boxes were reloaded, the reduction after each loading was calculated separately. Boxes 3 and 6, which were initially loaded with excavated pond soil that had contaminant levels below detection levels, were reloaded with tank area soil and percentage reductions were calculated only on this latter loading.

Overall reductions of the constituents varied depending on the remediation time span, the constituent concentrations, and the presence or absence of manure. Boxes 1 and 5 (loaded twice with tank soil) had PAH reductions of 51% to 60% and PCP reductions of 48% to 73%, while the boxes loaded once with tank soil had PAH reductions of 75% to 100% and PCP reductions of 33% to 96%. Effects of the time span, concentration levels, and presence of manure can best be seen by comparing Boxes 2, 3, 4, and 6. All four boxes were loaded once with variations in the concentrations of constituents, remediation time, and the presence or absence of manure (Table 8).

The best overall percentage reduction occurred in Box 2 which contained moderate starting constituent concentrations and the highest level of manure. The next highest reduction percentage occurred in Box 6 which had the lowest starting levels of hazardous constituents and half the level of manure contained in Box 2. The lowest reduction occurred in Box 4 which had the highest starting levels of hazardous constituents and no added manure.

Tetrachlorophenol (TeCP) also had fairly rapid disappearance rates (Table 7). The levels of TeCP followed the same trends that were observed for the

PAHs and PCP and seemed to depend on the same factors, especially the initial concentration of the constituents and the presence of manure. No TeCP was found at the 2-foot level in any of the boxes at the end of the study.

Some reductions in octachlorodibenzo-p-dioxin (OCDD) occurred in Boxes 1, 2, 5, and 6 (Table 7). The levels of OCDD in this study are close to the method detection limits and the variability of the analytical results is high so these results, while interesting, are not to be taken as an indication of remediation of OCDD.

The total bacteria and acclimated bacteria for the individual boxes are shown in Figure 2. In all six boxes, several trends can be noted. During the start of the experiment (10/28/89), the ratio of acclimated bacteria/total bacteria counts was less than 50%. As the study progressed, the ratio increased to 90%. Large increases in the number of bacteria occurred during the summer months in all boxes except Box 4, the only box that did not contain chicken manure. The lowest total bacteria counts and acclimated bacteria counts were found in Box 4.

In general, the disappearance rates in the boxes were excellent. Bacteria levels were high and good disappearance rates were found at high contaminant levels (e.g. Box 4 with 13,655 ppm PAHs and 1000 ppm PCP). These results confirmed the laboratory results (Phase 1) and expanded the conclusion to longer time periods (1 year) and field conditions.

The initial high surface soil content of the metals studied (arsenic, copper, chromium, and zinc) tended to become equilibrated throughout all three depths by the end of the study (data not shown).

No drainage water was found in the boxes until heavy rains occurred in March 1989. The drainage water was analyzed for organic constituents for samples taken on 4/05/89, 6/14/89, 8/02,89, and 10/02/89. The results are given in Table 9.

Parts per billion levels of PCP were found in the box drainage water and generally decreased from 4/05/89 to 10/02/89. Boxes 1, 3, 4, and 5 had the highest levels. These boxes were loaded with the highest level of contaminants.

Levels of PAHs in the parts per billion range were also found in the drainage water. The PAH concentrations in drainage water from some boxes increased and others decreased with no apparent consistent pattern. The distribution of the various PAHs (data not shown) indicated that the products moved in the oil phase. When PAHs move in the water phase, the major constituents moving are the lower molecular weight compounds (e.g. bicyclics and tricyclics). In contrast, movement of PAHs in the oil phase favors the movement of the higher molecular weight PAHs. The metal concentrations in the drainage water are given in Table 10. The major metal constituents found in the drainage water were arsenic and zinc which are more water soluble than the other metals under these conditions.

Table 1: CALENDAR OF PHASE 2 ACTIVITIES

October 6, 1988	Boxes 1 and 4 were loaded with 12 inches of soil from the tank area, Boxes 2 and 5 were loaded with 6 inches of soil from the tank area, and Boxes 3 and 6 were loaded with 12 inches of soil from the Roseburg excavated pond.
October 28, 1988	Soil samples were taken--no drainage water was found.
December 12, 1988	Soil samples were taken--no drainage water was found except in Box #1.
April 14, 1989	Soil and drainage water samples were taken. Four of the water sample containers were lost during shipment, so analyses are not available. Box 3 was reloaded with 12 inches of soil from the tank area and 6 inches of chicken manure. Box 5 was reloaded with 24 inches of tank area soil and 6 inches of chicken manure.
June 6, 1989	Soil and water samples were taken. Box 1 was loaded with 6 inches of tank area soil and 12 inches of chicken manure. Box 2 was loaded with 12 inches of chicken manure. Box 6 was reloaded with 12 inches of tank area soil and 6 inches of chicken manure.
July 5, 1989	Soil samples were collected.
July 31, 1989	Soil and water samples were collected.
September 7, 1989	Soil and water samples were collected.
October 18, 1989	Soil and water samples were collected.

Table 2: NITROGEN, CARBON, PHOSPHORUS, CHLORIDE ION, AND PH IN WEED SOIL SAMPLES

Sample	Kjeldahl nitrogen	Organic carbon	Phosphorus	Chloride	pH
	(ppm)				
Tank	5680	241400	1320	3.6	6.44
Retort	1955	68730	480	9.4	7.78
Sump	2335	69960	2090	8.3	7.90
Spray field	2765	63650	338	6.6	7.13
Drip pads	1350	35640	540	9.6	7.62
Excavated pond	765	10720	410	8.5	6.95

Table 3: METALS IN WEED SOIL SAMPLES

Sample	Copper	Chromium	Zinc	Arsenic
	Metals (ppm)			
Tank	10.6	144.7	23.9	23.1
Retort	19.0	401.0	37.5	18.2
Sump	32.1	321.2	33.3	19.0
Spray field	15.3	387.3	56.2	15.2
Drip pads	29.7	290.2	34.2	21.3
Excavated pond	24.3	269.8	56.2	18.

Table 4: PCP AND TECP IN WEED SOIL SAMPLES (PPM)[a]

Sample	Day 0		Day 14		Day 28		Day 56		Day 84	
	PCP	TeCP	PCP	TeCP	PCP	TeCP	PCP	TeCP	PCP	TeCP
Tank	2267	236	2927	273	2480	223	1593	220	1490	200
Tank 1/2	1153	113	954	87	857	91	897	84	663	100
Tank 1/4	714	61	336	25	345	28	364	26	315	25
Tank IF	2780	287	2883	257	2777	243	1470	270	1583	227
Tank 1/2 IF	1120	113	937	87	879	85	802	77	543	38
Tank 1/4 IF	556	50	400	30	339	28	336	27	324	27
Retort	68	ND	98	ND	47	ND	56	ND	43	ND
Retort 1/2	28	ND	ND	ND	20	ND	ND	ND	13	ND
Retort 1/4	ND[b]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Retort IF	80	ND	82	ND	63	ND	51	ND	47	ND
Retort 1/2 IF	46	ND	30	ND	28	ND	29	ND	15	ND
Retort 1/4 IF	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sump	370	ND	226	ND	160	ND	180	ND	74	ND
Sump IF	554	ND	236	ND	198	ND	173	ND	95	ND
Spray Field	ND	ND	ND	ND	NA[c]	NA	NA	NA	NA	NA
Spray Field IF	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
Drip Pads	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
Drip Pads IF	ND	ND	ND	ND	NA	NA	NA	NA	NA	NA
Excavated Pond	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Excavated Pond IF	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

[a]Each number represents an average of three replications.

[b]ND = not detected.

[c]NA = not analyzed.

Note: In this and the following tables, 1/2 and 1/4 refer to dilutions of the sample soil with control soil. IF refers to added inorganic fertilizer.

Table 5: TOTAL PAHs IN WEED SOIL SAMPLES (PPM)

Sample	Day 0	Day 14	Day 28	Day 56	Day 84
Tank	14624	16311	11615	10226	6611
Tank 1/2	7824	5211	4661	3058	2522
Tank 1/4	3781	2274	2250	1477	1778
Tank IF	17116	17600	16277	14993	16936
Tank 1/2 IF	7255	4927	3822	2977	1314
Tank 1/4 IF	3904	1927	1978	1528	2272
Retort	2529	2314	1805	1203	844
Retort 1/2	1278	598	445	410	423
Retort 1/4	348	305	504	90	457
Retort IF	2291	1733	1430	1375	1239
Retort 1/2 IF	1551	878	733	572	581
Retort 1/4 IF	391	230	179	362	ND
Sump	884	840	608	705	529
Sump IF	1051	778	629	649	573
Spray Field	ND[a]	ND	NA[b]	NA	NA
Spray Field IF	ND	ND	NA	NA	NA
Drip Pads	62	ND	NA	NA	NA
Drip Pads IF	53	ND	NA	NA	NA
Excavated Pond	1095	700	579	464	215
Excavated Pond IF	1061	581	455	429	319

[a]ND = not detected.
[b]NA = not analyzed.

Table 6: RATE CONSTANTS AND HALF LIVES FOR TOTAL PAHs AND PCP[a]

Sample	Total PAHs		PCP	
	Rate Constant (day 1)	Half Life (days)	Rate Constant (day 1)	Half Life (days)
Tank	-0.0100	69	-0.0073	95
Tank 1/2	-0.0133	52	-0.0054	128
Tank 1/4	-0.0095	73	-0.0064	108
Tank IF	-0.0008	866	-0.0089	78
Tank 1/2 IF	-0.0218	33	-0.0207	34
Tank 1/4 IF	-0.0094	74	-0.0049	141
Retort	-0.0139	50	-0.0068	102
Retort 1/2	-0.0126	55	-0.1274	5
Retort 1/4	-0.0040	173	NF	
Retort IF	-0.0081	86	-0.0086	81
Retort 1/2 IF	-0.0105	66	-0.0107	65
Retort 1/4 IF	-0.0184	38	NF	
Sump	-0.0055	126	-0.0174	40
Sump IF	-0.0065	107-	0.0174	40
Spray Field	NF[b]	NF		
Spray Field	NF	NF		
Drip Pads	-0.2940	2	NF	
Drip Pads IF	-0.2828	2	NF	
Excavated Pond	-0.0162	43	NF	
Excavated Pond IF	-0.0124	56	NF	

[a] These values are estimates calculated with a first order rate equation using beginning and ending concentrations of total PAHs and PCP.

[b] NF = no compounds (PAHs or PCP) found.

Table 7: OVERALL REDUCTIONS OF WEED BOXES

		Initial Values (ppm)				Final Values (ppm)				Reduction %			
Months	Box #	PAHs	PCP	OCDD	TeCP	PAHs	PCP	OCDD	TeCP	PAHs	PCP	OCDD	TeCP
	#1[a]												
5	Surface	8938	641	1.55	68	2647	149	3.58	13	70%	76%		
	1 ft.	787	34	0	2.1	1780	97	0.41	0	--	--		
	2 ft.	2056	104	0.64	9.5	927	49	0	0	55%	53%		
	(overall)									(55%)	(62%)		(84%)
	#1[b]												
4	Surface	2960	742	2	49	134	57.5	0	0	95%	92%		
	1 ft.	3383	502	2.8	36	3762	410	2.64	32	--	18%	58%	
	2 ft.	3058	535	1.55	41	214	18.2	0	0	93%	97%		
	(overall)									(56%)	(73%)	(58%)	(75%)
	#2												
9	Surface	4793	510	2.75	50.5	0	19.5	1.26	0	100%	96%		
	1 ft.	1109	85	0.71	8.5	0	4.59	0	0	100%	95%		
	2 ft.	1785	98	0.63	5.2	0	4.44	0	0	100%	95%		
	(overall)									(100%)	(96%)	(65%)	(100%)
	#3												
6	Surface	8591	723	7.5	72	305	259	4.2	5	96%	65%		
	1 ft.	441	36	0	0	494	227	5.29	12	--	--	--	
	2 ft.	155	8.03	0	2	0	26.6	0.65	0	100%	--	--	
	(overall)									(91%)	(33%)	(0%)	(77%)
	#4												
9	Surface	13,655	1075	4.77	130	2166	455	4.03	29	84%	58%		
	1 ft.	4701	233	1.36	22	3164	325	3.77	29	33%	--		
	2 ft.	3206	143	1.23	15.5	42	4.4	0	0	99%	97%		
	(overall)									(75%)	(46%)	(0%)	(69%)
	#5[c]												
3	Surface	9041	554	3.49	64	2018	107	1.08	7	78%	81%		
	1 ft.	3529	158	0.81	16	3662	154	1.67	11	--	4%		
	2 ft.	2602	98	0.84	7.5	330	16.5	0.17	0	87%	83%		
	(overall)									(60%)	(65%)	(43%)	(80%)
	#5[d,e]												
6	Surface	7398	711	5.6	63	170	53.4	5.88	0	97%	92%		
	1 ft.	2704	866	0	22	4194	859	5.18	67	--	1%		
	2 ft.	11	165	0	0	559	76.2	1.25	0	--	94%		
	(overall)									(51%)	(48%)	(0%)	(21%)
	#6												
4	Surface	3398	186	4.01	24	372	118	3.65	3	89%	37%		
	1 ft.	582	150	2.03	0	0	10.5	0.54	0	100%	93%		
	2 ft.	0	0	0	0	63	20.7	0.68	0	--	--		
	(overall)									(89%)	(56%)	(19%)	(87%)

[a] - Bioremediation from 10/6/88 to 6/6/89
[b] - Bioremediation from 6/6/89 to 10/10/89
[c] - Bioremediation from 10/6/89 to 12/12/89
[d] - Bioremediation from 4/14/89 to 10/18/89 - used
[e] - Used the PCP values from 7/5/89 as the initial values

Table 8: EFFECT OF CONCENTRATION ON REDUCTIONS IN PCP AND PAHs

Box #	Initial Concentration[a] (ppm) (months)	PAHs	PCP	Reduction (%) PAHs	PCP
2	9	7,687	693	100	96
3	6	9,187	767	91	33
4	9	21,562	1,451	75	46
6	4	3,908	336	89	56

[a] - Combined value at all depths

Table 9 WATER ANALYSIS FROM WEED BOXES

Box #	4/05/89	6/14/89	8/02/89	10/02/89
		Pentachlorophenol (ppm)		
1	[a]	0.83	0.26	0.024
2	[a]	0.039	ND	ND
3	[a]	1.34	ND	0.066
4	[a]	0.57	ND	ND
5	0.037	0.017	ND	0.023
6	ND	0.011	ND	ND
		Polycyclic Aromatic Hydrocarbons (ppm)		
1	[a]	0.74	ND	0.35
2	[a]	0.28	0.164	1.272
3	[a]	0.34	0.033	0.036
4	[a]	0.43	0.256	0.076
5	ND	0.17	0.015	0.47
6	ND	0.084	0.031	0.26

[a] - These bottles were broken during shipment

Table 10: METAL ANALYSIS FROM WEED BOXES

	Arsenic (ppm)	
Box #	8/02/89	10/02/89
1	3.08	2.40
2	0.64	0.35
3	0.83	1.73
4	2.24	2.79
5	0.93	1.42
6	0.10	0.026

	Chromium (ppm)	
Box #	8/02/89	10/02/89
1	0.0083	.140
2	ND	ND
3	0.052	0.053
4	0.003	0.010
5	0.063	0.168
6	ND	ND

	Copper (ppm)	
Box #	8/02/89	10/02/89
1	0.53	1.32
2	0.097	.040
3	0.30	.550
4	0.37	.66
5	0.36	1.31
6	0.065	0.036

	Zinc (ppm)	
Box #	8/02/89	10/02/89
1	20.47	11.72
2	25.15	6.54
3	2.94	14.43
4	10.48	9.69
5	15.80	5.73
6	5.66	2.37

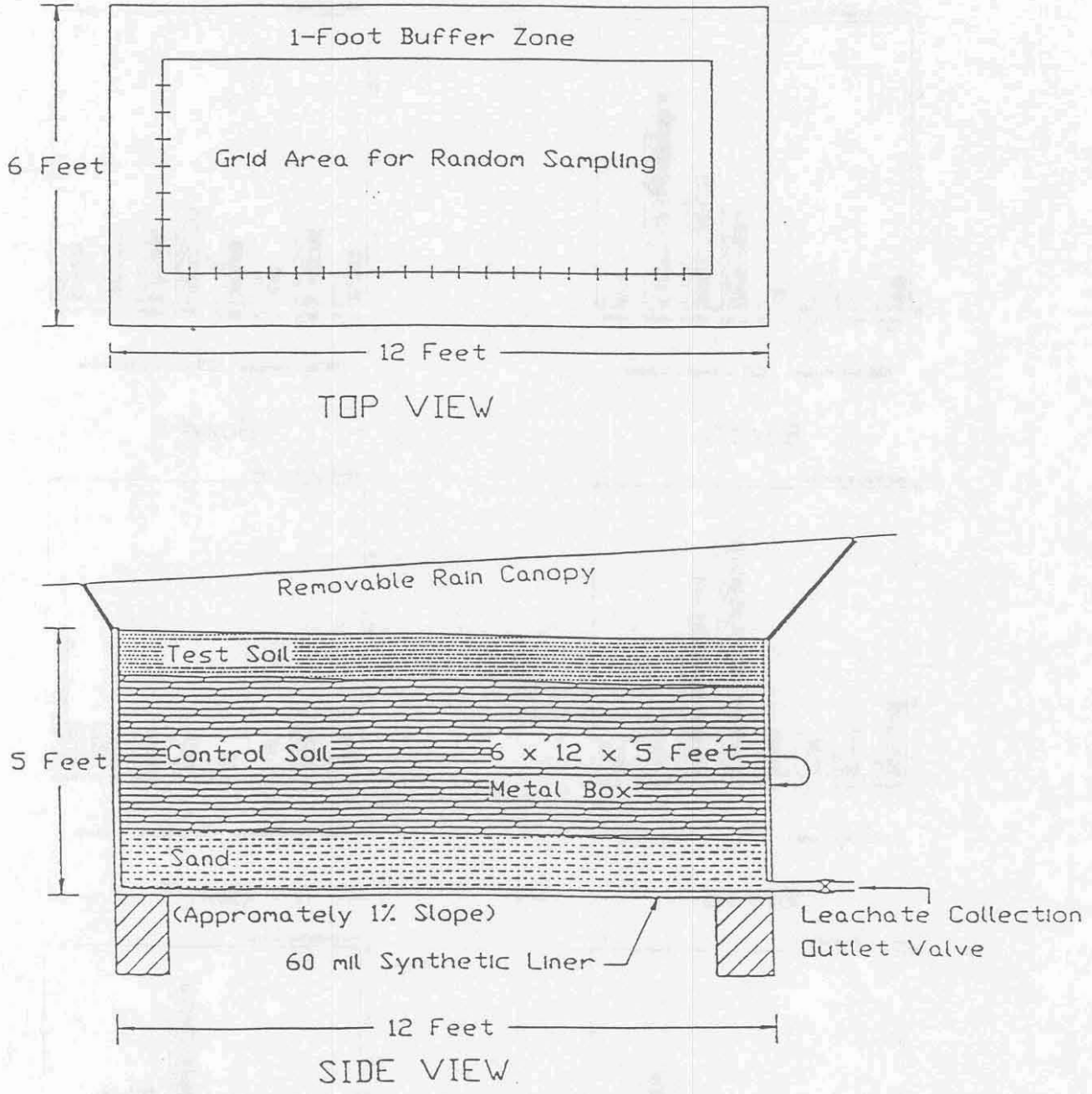

Figure 1. Design of steel boxes used for Phase 2 studies at Weed, California.

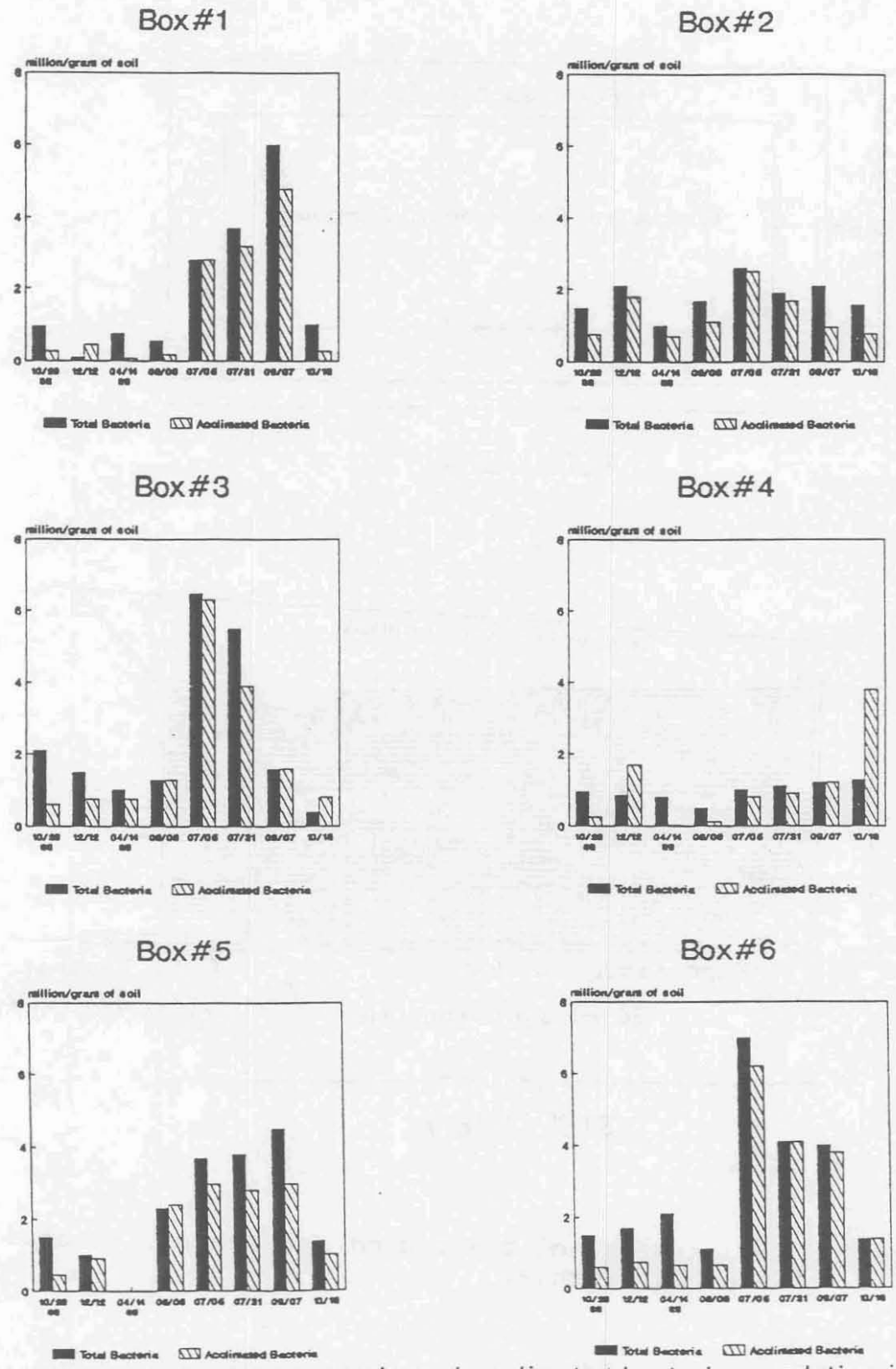

Figure 2 Change in the total bacteria and acclimated bacteria population in boxes