INORGANIC CHEMICALS IN GROUND WATER AND SOIL: BACKGROUND CONCENTRATIONS AT CALIFORNIA AIR FORCE BASES.

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ABSTRACT

Inorganic chemicals have widespread industrial use and are significant contaminants at many hazardous waste sites and industrial locations. Risk assessment and risk management must differentiate between background (naturally occurring) and anthropogenic inorganic chemicals. This distinction is important for site characterization, determining chemicals of concern, establishing cleanup levels, and long-term monitoring programs. This paper is an update of our 2001 report on background at Air Force bases in California.

The Air Force's Environmental Resources Program Information Management System (ERPIMS) database was searched for uncontaminated sample locations for soil and groundwater at 14 Air Force installations in 10 California counties. Background data for 27 inorganic constituents from 1,307 monitoring well locations yielded as many as 5,071 groundwater samples for individual chemicals, while 3,883 boreholes yielded as many as 10,415 soil samples. Medians, 95th, and 99th percentiles are reported for each chemical. Since statistical analysis of soil data indicated that background levels differed significantly with depth, separate background calculations for soil are presented for three depths (less than 3 feet, between 3 and 15 feet, and greater than 15 feet).

For groundwater, background statistics for each constituent are given without regard to sampling depth. Some inorganic constituents were detected frequently and at levels that exceed important environmental thresholds such as Maximum Contaminant Levels (MCLs) or Action Levels for drinking water. Background 95th percentile levels equal or exceed federal and/or California MCLs for aluminum, antimony, cadmium, chromium, nickel, and thallium. The 95th percentile level for lead exceeds the Action Level of 0.015 mg/L for drinking water measured at the tap. This analysis provides background levels that are representative of California Air Force Bases as a group. The background data in this presentation should not be used to replace local background data, but rather provide important benchmarks by which the adequacy of local data can be judged.

INTRODUCTION

Risk assessment of inorganic chemicals for human and ecological receptors requires the parsing of concentrations and associated risk, into portions attributable to anthropogenic activities and portions that are naturally occurring. Background data can be used in the initial site investigation, for identification of chemicals of potential concern, in remedy selection, and for risk communication to the public. (Current USEPA guidance [2002] recommends including all inorganic chemicals in risk assessment and considering the relative contributions of naturally occurring versus anthropogenic chemicals during risk characterization and risk management.)

Computer algorithms were applied to identify background locations at Air Force Bases (AFBs) in California, based on the absence of organic contaminants. This paper presents an update, with substantial increases in data, compared to the summaries of background data in groundwater and soil in Hunter and Davis, 2001. Sample sizes increased by over 40% for soil and by almost 200% for groundwater. These results should not be used in lieu of site-specific background concentrations. They can, however, provide a useful perspective for site-specific results.

METHODS

A computer algorithm was constructed to identify background locations at 14 California Air Force bases, using data from 1984 - 2004. The algorithm, using Structured Query Language, searches out all locations that have been sampled for both inorganic and organic chemicals. Sampling locations with organic contamination (at levels greater than twice the method detection limit) are eliminated. The most common 25 organic contaminants in groundwater were used for groundwater and the most common 25 organic chemicals in soil were similarly applied. Upper-range outliers were eliminated for each inorganic constituent based on concentrations that exceeded "far-outside" values in "box and whisker" plots. Upgradient, downgradient, and sidegradient locations were all potential background sampling locations. Substantially more background locations were identified in soil than in groundwater. On average, 50 background well locations and 100 background borehole locations have been identified per AFB.

This analysis is complicated by different analytical laboratories, various sampling strategies, multiple detection limits, diverse hydrogeologic terrains, variability over 3-dimensional space, a variety of types of hazardous waste sites, multiple Air Force bases, and different waste handling practices. These result in the discrimination of background levels across more than one hydrostratigraphic unit or more than one soil horizon. Given the large sample sizes, percentiles are reported without confidence limits. SAS® and Systat® software generated the statistics shown in the tables. The groundwater data represent dissolved, field-filtered, and total recoverable results.

BACKGROUND ANALYSIS FOR GROUNDWATER

- 1,307 background wells were identified and analyzed from a universe of 6,290 available monitoring wells
- Range of number of Air Force Bases: 5 for boron to 13 for many constituents
- Data are biased, with Vandenberg, Travis and March AFBs representing 75% of the total data
- Range of background wells: 148 for Cr-6 to 1307 for Pb
- Range of sample sizes: 243 for Cr-6 to 5071 for Pb
- Range of detection rates: 2% for Ag to 99.8% for Mg
- Distributions did not fit either a normal or lognormal distribution
- The 95th percentiles for Al, Sb, Cd, Cr, Ni, and Tl exceed the respective MCLs (Maximum Contaminant Levels for drinking water), both California and USEPA; the 95th percentile for Pb exceeds its USEPA Action Level for drinking water

GROUNDWATER DATA FROM AIR FORCE BASES IN CALIFORNIA

Analyte	n	Percentile in ug/L			Detection	Median Method Detection	Number Wells	Number AF Bases
		50th	95th	99th				
Aluminum	3560	100	32,500	118,000	51%	70	968	12
Antimony	4084	*ND*	146	190	6%	26	1084	12
Arsenic	3983	*ND*	35	140	23%	3	1043	13
Barium	3680	90	630	2,100	94%	6	1011	13
Beryllium	4160	*ND*	*ND*	5	5%	2	1104	12
Boron	560	83	1,800	16,000	84%	30	286	5
Cadmium	4396	*ND*	6	42	11%	4	1176	13
Chloride	2184	142,000	1,000,000	3,120,000	99%	500	855	11
Chromium	4335	*ND*	810	5,390	37%	5	1157	13
Chromium-6	243	*ND*	25	60	36%	4	148	9
Cobalt	3686	*ND*	25	95	13%	10	993	12
Copper	4786	*ND*	50	220	19%	12	1094	13
Cyanide	580	*ND*	12	30	6%	10	269	9
Fluoride	1005	400	1,300	1,850	90%	100	557	9
Iron	4508	225	41,000	193,000	74%	20	1054	12
Lead	5071	*ND*	50	220	16%	4	1307	13
Magnesium	4731	23,200	153,000	390,000	100%	36	1075	13
Manganese	4523	46	2,150	5,800	79%	3	1043	12
Mercury	3599	*ND*	0.5	3	7%	0.2	965	13
Molybdenum	3594	*ND*	79	122	23%	6	958	11
Nickel	4200	*ND*	455	1,470	38%	22	1090	13
Selenium	3861	*ND*	31	200	12%	5	1027	13
Silver	4314	*ND*	15	20	2%	3	1163	13
Sodium	4719	85,800	588,000	2,080,000	100%	240	1083	13
Thallium	3965	*ND*	200	300	4%	100	1003	12
Vanadium	3497	16	110	464	62%	7	935	12
Zinc	4835	20	220	990	68%	10	1113	13

BACKGROUND ANALYSIS FOR SOIL

- 4230 background boreholes were identified and analyzed from a universe of 10,030 available boreholes
- Range of number of Air Force Bases: 2 for Cl to 13 for As
- Data are biased, with Vandenberg, March, and Edwards AFBs representing 50% of the total data
- Range of background boreholes: 126 for Fl to 3,883 for Pb
- Range of sample sizes: 354 for Fl to 10,415 for Pb
- Range of detection rates: 2% for Cn to > 99% for Fe, Mn, Ba, and V
- None of the distributions fit either a normal or lognormal distribution
- The 95th percentiles for As, Fe, Tl, and V exceed their respective USEPA Region 9 Preliminary Remediation Goals (residential, health-based concentrations)

SOIL DATA FROM AIR FORCE BASES IN CALIFORNIA

Analyte	n	Percentile (mg/kg)			Detection	Median Method Detection Limit	Number Boreholes	Number AF Bases
		50th	95th	99th				
Aluminum	7473	7,560.0	23,000.0	31,300.0	97%	10.4	3027	12
Antimony	9065	*ND*	12.5	25.0	7%	6.3	3522	12
Arsenic	8665	2.2	12.7	23.2	61%	0.6	3193	13
Barium	8340	67.3	320.0	584.0	100%	1.0	3218	12
Beryllium	8242	0.3	1.1	5.6	54%	0.2	3211	12
Boron	435	44.9	140.0	201.0	93%	3.2	146	3
Cadmium	9367	*ND*	2.3	7.7	18%	0.5	3691	12
Chloride	572	10.2	629.0	1,730.0	94%	0.2	257	2
Chromium	10051	11.6	49.4	100.0	94%	1.0	3821	12
Chromium-6	2060	*ND*	2.0	5.0	10%	0.2	650	9
Cobalt	7163	5.8	22.0	35.9	85%	1.0	2908	12
Copper	9441	9.9	53.3	157.0	95%	1.3	3671	12
Cyanide	1198	*ND*	0.7	3.0	2%	0.5	525	10
Fluoride	354	1.1	8.9	23.0	82%	0.5	126	3
Iron	8003	12,500.0	36,100.0	49,400.0	100%	5.4	3141	12
Lead	10415	3.1	25.0	148.0	66%	2.0	3883	12
Magnesium	6985	3,280.0	9,520.0	16,200.0	97%	20.0	2814	11
Manganese	7964	208.0	823.0	1,600.0	100%	1.0	3122	12
Mercury	7702	*ND*	0.3	0.6	10%	0.1	2719	12
Molybdenum	6967	*ND*	20.0	44.0	16%	2.0	2752	12
Nickel	9390	7.1	41.5	85.4	72%	2.2	3633	12
Selenium	8656	*ND*	11.0	25.0	7%	0.6	3182	12
Silver	9669	*ND*	2.1	6.1	6%	1.0	3727	12
Sodium	5907	222.0	1,660.0	3,980.0	83%	60.8	3503	11
Thallium	8639	*ND*	25.0	173.5	8%	5.0	3352	12
Vanadium	7971	27.4	88.3	126.0	99%	1.0	3168	12
Zinc	9981	31.2	104.0	307.0	99%	1.1	3870	12

VARIABILITY OF SOIL BACKGROUND LEVELS WITH DEPTH

A frequency distribution analysis of sampling depths indicated that the soil sample data could be divided into three horizons of approximately equal sample sizes. These horizons are: 1) surface to 3 feet, 2) 3 feet to 15 feet, and 3) greater than 15 feet. Separate background concentrations by depth were derived for all analytes. No consistent pattern relates concentration and depth. Lead concentrations decrease markedly with depth (95^{th} percentiles are 59.2 mg/kg, 20.0 mg/kg, and 11.7 mg/kg), iron concentrations increase with depth (95^{th} percentiles are 33,000 mg/kg, 36,100 mg/kg, and 40,000 mg/kg), and chromium concentrations are about constant (95^{th} percentiles are 48.9 mg/kg, 49.9 mg/kg, and 49.6 mg/kg).

SOIL DATA FROM SURFACE TO 3 FEET

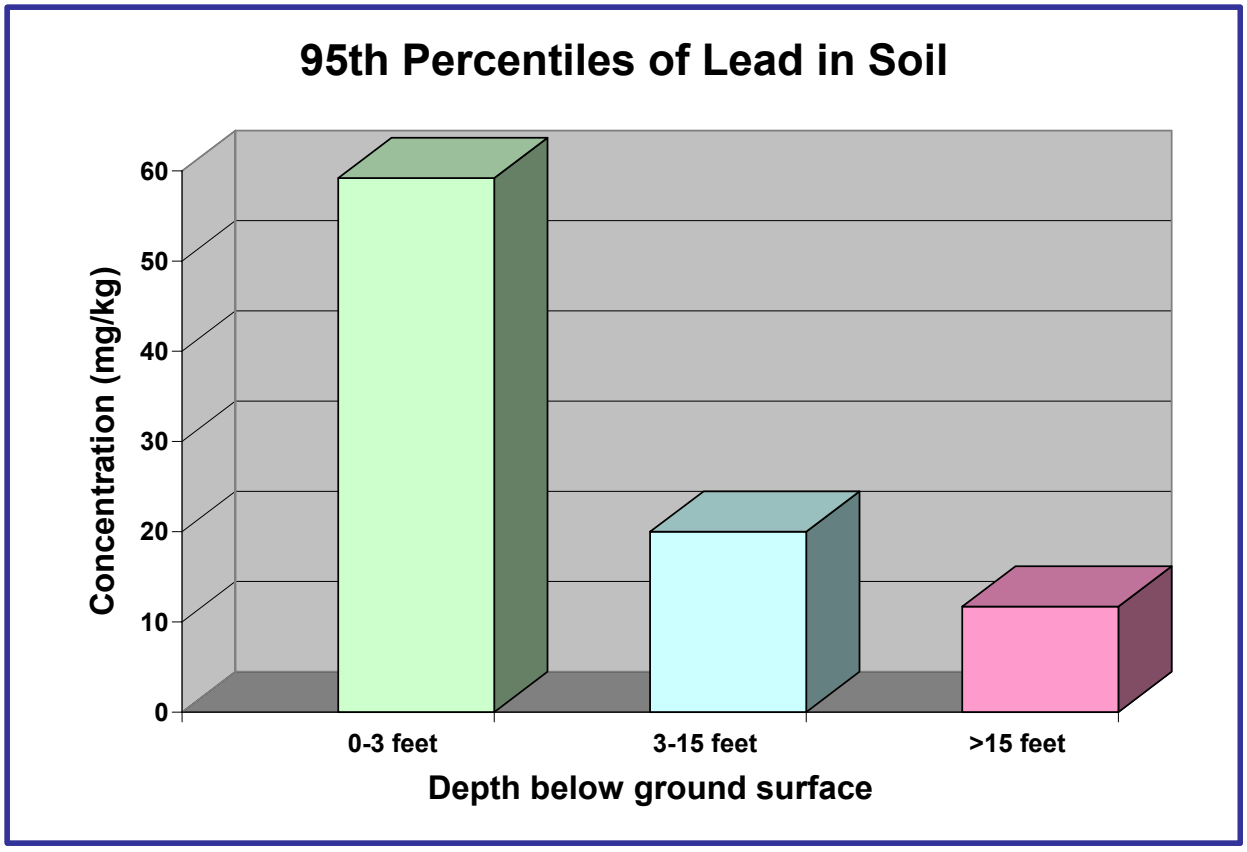
Analyte	n	Percentile (mg/kg)			Detection	Median Method Detection Limit	Number Boreholes	Number AF Bases
		50th	95th	99th				
Aluminum	2718	7,615.0	22,100.0	28,400.0	98%	10.1	2042	11
Antimony	3003	*ND*	12.0	25.0	9%	6.1	2311	11
Arsenic	2807	2.4	12.6	23.2	69%	0.5	2051	12
Barium	2895	74.0	316.0	596.0	100%	1.0	2141	11
Beryllium	2748	0.3	1.1	2.1	57%	0.2	2112	11
Boron	105	6.1	116.0	136.0	82%	3.2	93	3
Cadmium	3101	*ND*	2.7	10.6	23%	0.5	2362	11
Chloride	224	7.6	419.0	1,100.0	94%	0.2	169	2
Chromium	3297	13.3	48.9	144.0	97%	1.0	2482	11
Chromium-6	560	*ND*	3.3	5.9	13%	0.2	431	9
Cobalt	2444	6.0	21.0	34.1	87%	1.0	1847	11
Copper	3163	11.9	52.7	221.0	97%	1.0	2390	11
Cyanide	422	*ND*	0.6	25.5	3%	0.5	354	9
Fluoride	125	1.0	8.9	18.0	79%	0.5	103	3
Iron	2797	12,600.0	33,000.0	45,600.0	100%	5.2	2094	10
Lead	3312	5.2	59.2	348.0	72%	2.0	2414	11
Magnesium	2436	3,130.0	8,730.0	19,900.0	98%	20.0	1856	10
Manganese	2790	224.0	810.0	1,400.0	100%	1.0	2082	11
Mercury	2471	*ND*	0.2	0.7	13%	0.1	1798	11
Molybdenum	2373	*ND*	20.3	44.0	19%	2.0	1785	11
Nickel	3078	8.3	38.8	127.0	76%	1.5	2345	11
Selenium	2806	*ND*	10.5	25.0	9%	0.6	2056	11
Silver	3251	*ND*	2.0	10.0	7%	0.6	2452	11
Sodium	2053	181.0	1,510.0	4,520.0	82%	51.7	1584	10
Thallium	2886	*ND*	25.0	169.5	8%	5.0	2210	11
Vanadium	2802	28.0	88.0	133.0	99%	1.0	2096	11
Zinc	3341	34.0	125.0	518.0	99%	1.1	2542	11

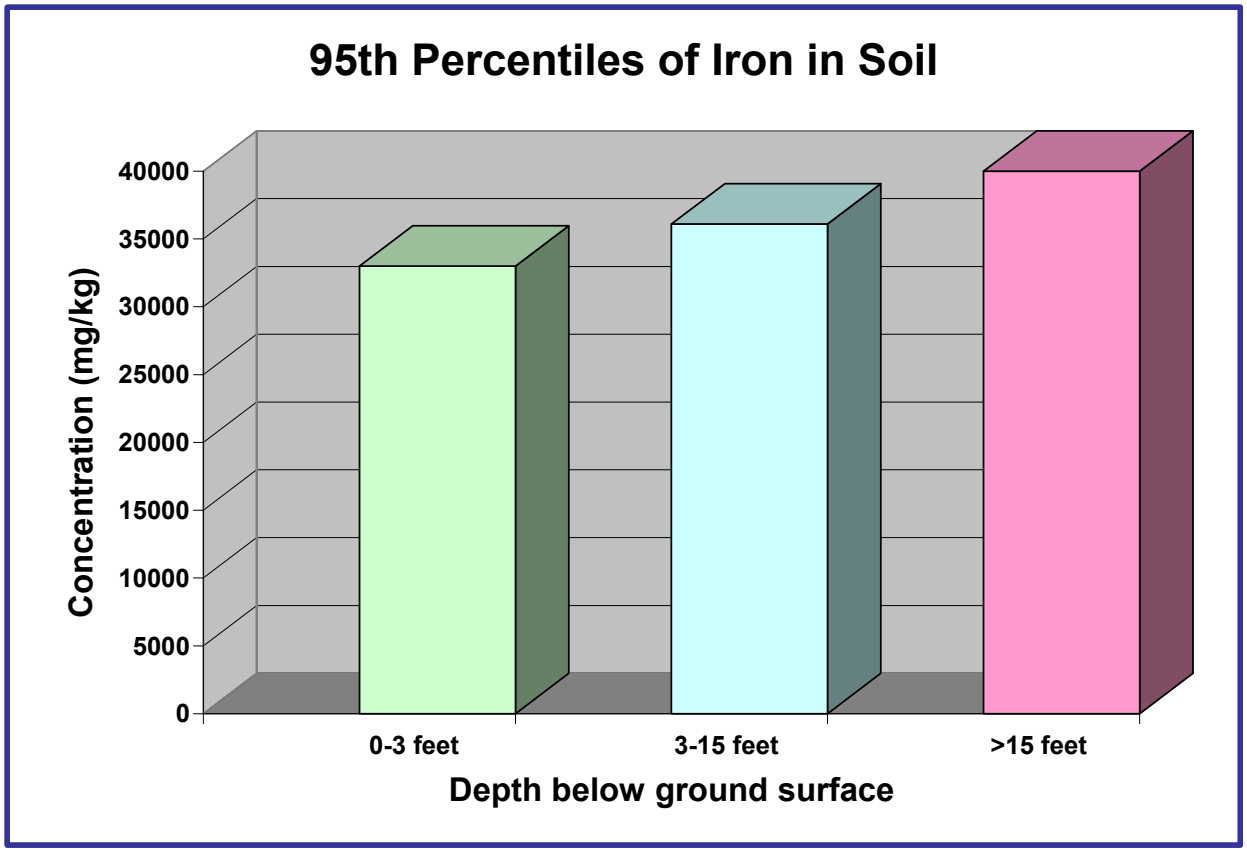
SOIL DATA FROM 3 FEET TO 15 FEET

Analyte	n	Percentile (mg/kg)			Detection	Median Method Detection Limit	Number Boreholes	Number AF Bases
		50th	95th	99th				
Aluminum	2961	7,870.0	23,400.0	32,100.0	96%	10.0	1685	11
Antimony	3306	*ND*	13.0	30.0	8%	6.1	1940	11
Arsenic	3145	2.3	15.0	33.9	66%	0.5	1752	11
Barium	3149	70.4	357.0	624.0	100%	0.5	1765	11
Beryllium	2897	0.3	1.1	5.9	54%	0.2	1710	11
Boron	196	50.0	116.0	136.0	99%	3.7	99	3
Cadmium	3360	*ND*	2.5	7.7	15%	0.5	1976	11
Chloride	187	8.9	638.0	2,600.0	96%	0.2	2	2
Chromium	3637	13.8	49.9	94.0	96%	1.0	2078	11
Chromium-6	670	*ND*	2.5	4.4	13%	0.2	397	9
Cobalt	2647	6.4	20.7	35.0	83%	1.0	1537	11
Copper	3395	10.4	56.0	167.0	96%	1.0	1948	11
Cyanide	462	*ND*	0.6	1.3	1%	0.6	235	8
Fluoride	130	1.2	9.3	25.0	82%	0.5	77	1
Iron	3024	13,400.0	36,100.0	47,200.0	100%	5.3	1733	10
Lead	3862	3.2	20.0	89.0	66%	1.8	2081	12
Magnesium	2553	3,550.0	9,770.0	15,400.0	93%	20.0	1477	10
Manganese	3032	207.0	787.0	1,500.0	100%	1.0	1477	11
Mercury	2863	*ND*	0.3	0.6	11%	0.1	1635	11
Molybdenum	2547	*ND*	21.0	42.0	20%	2.0	1485	11
Nickel	3425	8.2	41.8	89.3	75%	1.2	1964	11
Selenium	3228	*ND*	11.0	48.0	10%	0.5	1803	11
Silver	3539	*ND*	2.0	5.0	5%	0.6	2042	11
Sodium	2305	250.0	1,980.0	4,010.0	88%	40.0	1338	10
Thallium	3049	*ND*	25.0	171.5	7%	2.2	1795	11
Vanadium	3027	28.6	86.0	127.0	100%	1.0	1727	11
Zinc	3707	31.6	93.2	250.0	99%	1.0	2109	11

SOIL DATA DEEPER THAN 15 FEET

Analyte	n	Percentile (mg/kg)			Detection	Median Method Detection Limit	Number Boreholes	Number AF Bases
		50th	95th	99th				
Aluminum	1794	7,010.0	23,600.0	34,400.0	96%	11.0	836	12
Antimony	2756	*ND*	12.5	18.0	8%	6.6	1096	12
Arsenic	2713	1.5	10.0	20.0	66%	0.6	1025	12
Barium	2296	56.5	257.0	493.0	100%	1.1	901	12
Beryllium	2597	0.3	1.2	5.8	54%	0.2	1034	11
Boron	134	47.0	147.0	160.0	99%	3.0	62	3
Cadmium	2906	*ND*	1.8	4.7	15%	0.5	1170	12
Chloride	161	17.0	802.0	6,510.0	96%	0.2	95	2
Chromium	3117	8.0	49.6	88.3	96%	1.1	1205	12
Chromium-6	830	*ND*	1.0	4.0	13%	0.1	183	8
Cobalt	2072	5.0	24.3	38.7	83%	1.1	838	12
Copper	2883	6.4	51.5	109.0	96%	2.0	1117	12
Cyanide	314	*ND*	0.7	1.7	1%	0.5	109	7
Fluoride	99	1.4	7.3	29.0	82%	0.5	43	1
Iron	2182	11,100.0	40,000.0	52,800.0	100%	5.6	895	12
Lead	3241	2.7	11.7	22.5	66%	2.0	1274	12
Magnesium	1996	3,040.0	9,690.0	13,600.0	93%	21.7	821	11
Manganese	2142	182.5	930.0	2,010.0	100%	1.1	883	12
Mercury	2368	*ND*	0.3	0.4	11%	0.1	877	11
Molybdenum	2047	*ND*	20.0	44.0	20%	2.2	833	12
Nickel	2887	5.0	43.8	68.5	75%	4.1	1146	12
Selenium	2622	*ND*	11.5	14.0	10%	0.6	1000	12
Silver	2879	*ND*	2.4	5.4	5%	1.0	1127	12
Sodium	1549	216.0	1,180.0	2,700.0	88%	108.0	718	11
Thallium	2704	*ND*	25.0	176.0	7%	5.0	1074	12
Vanadium	2142	24.4	90.7	120.0	100%	1.1	871	12
Zinc	2933	27.1	99.6	180.0	99%	2.1	1181	12


95th Percentiles of Lead in Soil
Concentration (mg/kg)
60
50
40
30
20
10
0
0-3 feet
3-15 feet
>15 feet
Depth below ground surface


95th Percentiles of Iron in Soil
Concentration (mg/kg)
40000
35000
30000
25000
20000
15000
10000
5000
0
0-3 feet
3-15 feet
>15 feet
Depth below ground surface

SUMMARY AND CONCLUSIONS

- Computer algorithms identified background locations, based on the absence of organic contamination, for 27 inorganic chemicals in groundwater and soil at California Air Force Bases.
- The 95th percentile is a good representation of background concentration, given the inherent complexities of these large and diverse samples.
- Concentrations of some inorganic chemicals vary considerably by soil depth.
- For some inorganic chemicals the 95th percentile exceeds health-based criteria of concern.
- Concentrations and statistics for the inorganic chemicals have not changed significantly since our previous report (Hunter and Davis, 2001).
- These data provide insight on background variability across a range of environments, but do not necessarily represent all areas of California.
- These results can provide a useful context, but they cannot substitute for site-specific background concentrations.

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DISCLAIMER

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