

**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 (95th percentiles are 59.2 mg/kg, 20.0 mg/kg, and 11.7 mg/kg), iron concentrations increase with depth (95th percentiles are 33,000 mg/kg, 36,100 mg/kg, and 40,000 mg/kg), and chromium concentrations are about constant (95th 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 |

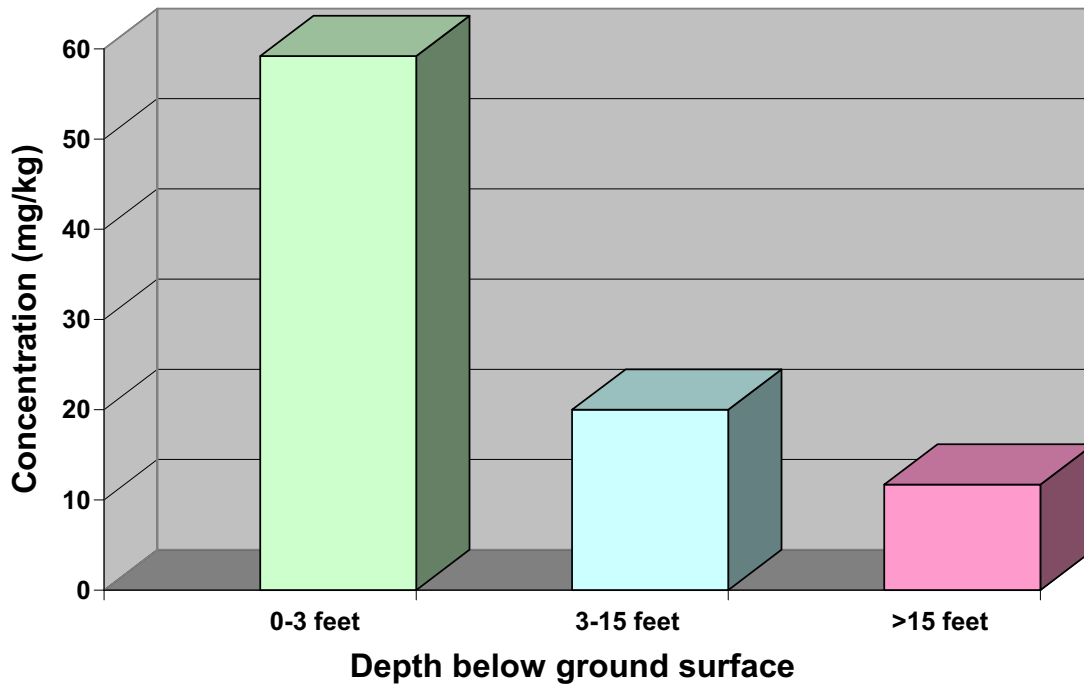
SOIL DATA FROM 3 FEET TO 15 FEET

| 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 |

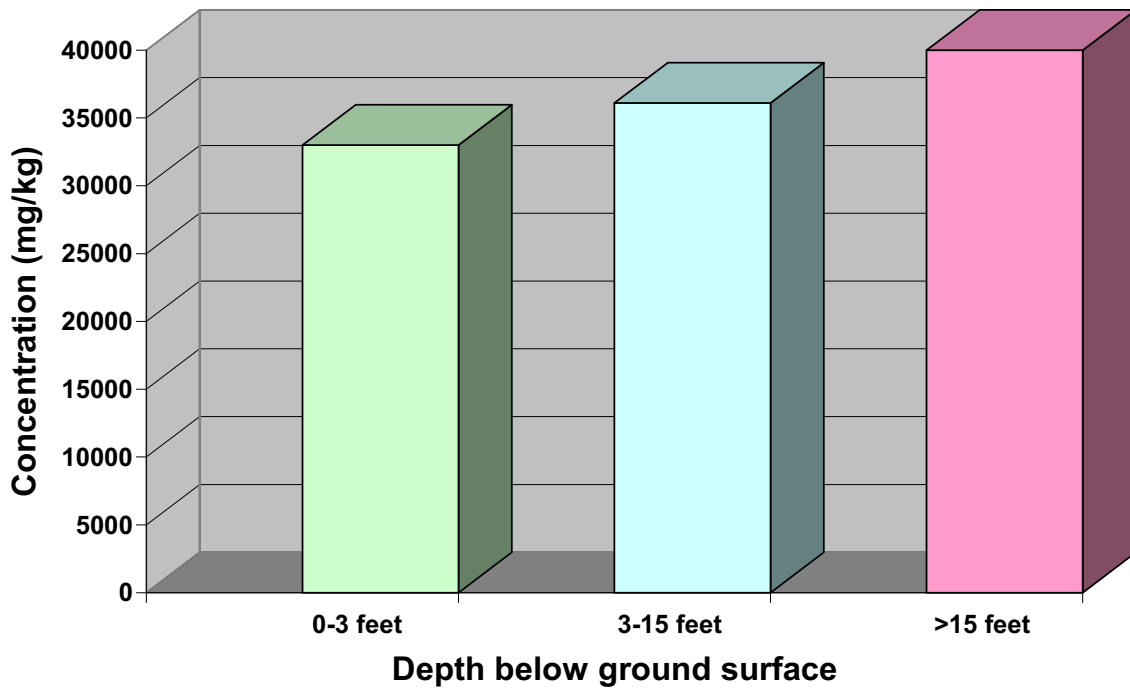
SOIL DATA DEEPER THAN 15 FEET

| 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



95th Percentiles of Iron in Soil



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

The opinions and findings in this paper are those of the authors. They do not represent guidance or policy of the California Department of Toxic Substances Control, California Environmental Protection Agency, or the U.S. Air Force.