Background Metal Concentrations in Oklahoma Soils

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Trace element concentrations vary naturally in native soils primarily due to differences in mineral composition and the chemical characteristics of the parent material (Adriano, 2001). Anthropogenic sources such as the input of fertilizers, pesticides and other soil amendments such as biosolids, animal manures and drilling mud may increase trace element levels in soils. For example, lead arsenate was used on cotton fields and orchards as a pesticide in the 1940s. Other activities that have affected metal concentrations in soils of Oklahoma include mining and smelting, emissions from different industries and the deposition of vehicle exhausts.

Metals may become an environmental problem when present at elevated concentrations due to their persistence, tendency to bioaccumulate, mobility and potential toxicity in the environment. Background metal concentrations of soils are often used as criteria for assessing environmental quality. Background levels must be determined to establish accurate and realistic guideline levels. Accurate background concentrations of metal and other trace elements allow regulators and consultants to make more informed decisions on the remediation of different soils with varying properties. Twenty-eight Oklahoma benchmark soils were collected from various locations representing major land resource areas across the state to establish the background levels of metals and trace elements in the state. The locations of the sampling sites are shown in Figure 1. The soils had no known history of applications of fertilizers, biosolids or manure within three years of collection. The soils were digested according to USEPA Method 3050B and analyzed for eight metals, one metalloid (arsenic) and one nonmetal (selenium) using inductively coupled plasma–atomic emission spectroscopy (ICP–AES). The concentrations of those elements (referred as metals thereafter) in the 28 benchmark soils are presented in Table 1. The concentrations of each element vary widely among different soils. Therefore, the median value presented at the bottom of the table would serve as a better background level for the state.

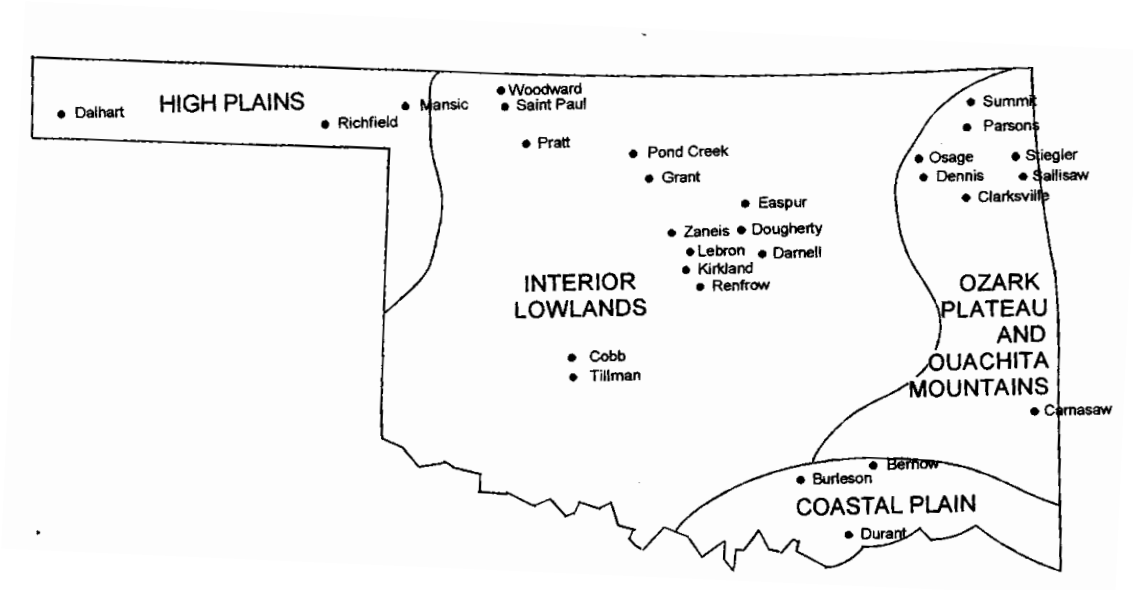

Figure 1. The delineation of major land resource areas in Oklahoma and the locations of the 28 benchmark soils used to establish the background metal concentrations (Scott, 1994; Zhang et al., 2005, Richards et al., 2012). The benchmark soils represent the diversity of soils in Oklahoma as well as the Major Land Resource Areas.

Table 1. Trace elements concentrations (parts per million or ppm, mg/kg) in the 28 benchmark soils of Oklahoma (Richards et al., 2012).

Soil	*As*	*Cd*	*Cr*	*Cu*	*Mn*	*Mo*	*Ni*	*Pb*	*Se*	*Zn*
Bernow	0.75	0.13†	4.83	2.13	27.4	0.31	2.41	5.45	<1.25	15.3
Burleson	4.93	0.36	53.7	14.3	580	1.25	21.6	19.1	<1.25	67.6
Carnasaw	12.8	0.66	51.0	8.43	1690	1.80	25.1	29.0	<1.25	63.2
Clarksville	2.95	0.30	16.7	11.9	2165	0.69	15.3	19.3	<1.25	59.1
Cobb	2.30	0.13†	10.7	5.78	106	0.26	7.46	6.04	<1.25	26.4
Dalhart	2.01	0.13†	7.14	3.78	98	0.26	5.46	4.23	<1.25	26.5
Darnell	1.13	0.13†	6.95	3.39	236	0.22	4.91	6.46	<1.25	24.6
Dennis	10.3	0.34	32.8	10.7	515	0.83	19.3	12.9	<1.25	53.0
Dougherty	1.08	0.13†	4.63	2.76	133	0.38	2.85	7.81	<1.25	40.8
Durant	4.72	0.13†	25.7	10.7	508	0.38	10.9	17.1	<1.25	45.2
Easpur	5.6	0.28	22.6	10.0	388	0.45	15.2	19.9	<1.25	57.3
Grant	3.19	0.25	20.1	9.36	383	0.46	14.3	11.9	<1.25	47.2
Kirkland	4.84	0.29	27.2	14.5	523	0.53	17.5	16.4	<1.25	61.2
Lebron	10.5	0.75	51.0	31.9	658	1.14	37.2	22.6	<1.25	106
Mansic	4.20	0.40	22.4	16.0	332	0.50	15.5	12.3	<1.25	61.4
Osage	9.16	0.80	54.1	31.2	725	0.84	38.0	27.6	<1.25	142
Parsons	24.4	0.73	57.0	20.1	853	1.29	29.4	28.8	<1.25	94.2
Pond Creek	2.93	0.25	19.6	11.5	409	0.41	13.9	12.0	<1.25	50.6
Pratt	1.45	0.13†	4.30	1.94	52.6	0.18	3.00	2.60	<1.25	20.9
Renfrow	3.73	0.13†	19.9	10.9	292	0.41	12.3	13.7	<1.25	41.7
Richfield	6.29	0.39	29.4	19.4	469	0.74	20.1	15.1	<1.25	79.5
St. Paul	4.18	0.13†	19.9	12.1	314	0.39	14.2	10.2	<1.25	47.8
Sallisaw	3.13	0.13†	19.7	11.3	1475	1.13	12.3	14.3	<1.25	51.7
Stiegler	3.74	0.13†	19.4	32.7	1601	0.53	10.7	20.2	<1.25	56.7
Summit	33.6	0.76	69.7	15.6	2119	1.00	57.3	31.7	<1.25	72.1
Tillman	4.34	0.13†	26.4	13.6	506	0.50	19.7	13.3	<1.25	56.7
Woodward	3.61	0.13†	19.9	10.4	293	0.36	16.2	7.49	<1.25	41.5
Zaneis	3.03	0.13†	16.8	6.43	166	0.43	9.91	9.41	<1.25	35.0
Mean	6.25	0.30	26.2	12.6	629	0.63	16.9	14.9	<1.25	55.2
Median	3.96	0.19	20.0	11.1	439	0.48	14.8	13.5	<1.25	52.4
Minimum	0.75	0.13	4.30	1.94	27.4	0.18	2.41	2.60	<1.25	15.3
Maximum	33.6	0.80	69.7	32.7	2165	1.80	57.3	31.7	<1.25	142

† The sample measured below the detection limit (BDL) of 0.25 mg/kg, but for statistical purposes, the BDL samples were replaced with one-half the detection limit. As (arsenic), Cd (cadmium), Cr (chromium), Cu (copper), Mn (manganese), Mo (molybdenum), nickel (Ni), lead (Pb), selenium (Se), and zinc (Zn).

Table 2 compares concentrations of background metals with the current USEPA Region 6 Screening Levels for these metals. The screening levels (SLs) were developed using risk assessment guidance from the EPA Superfund program (RAGS). The SLs are risk-based concentrations derived from standardized equations that combine exposure information and toxicity data and are intended to be protective of human health. The SLs are generic (i.e., they are calculated without site-specific information) and may be re-calculated using site-specific data. The Oklahoma Department of Environmental Quality (ODEQ) uses EPA Region 6 SLs to determine if a particular site requires clean-up. Usually, if metal concentrations are less than the SLs, no further action or study is required at a site (ODEQ, 2013). The industrial SLs apply to a situation which is not residential (i.e. low chance of regular human exposure) and use a different set of assumptions for the exposure information and calculations. The industrial SLs are often useful to consultants involved in environmental work such as site assessments, tank removals and remediation. Overall, the industrial SLs are not as conservative as the residential SLs. Generally, ODEQ uses the most conservative level for screening purposes. Certain chemicals, including metals, may produce either carcinogenic or noncarcinogenic toxicological effects or both. Therefore, both carcinogenic and noncarnogenic end points are evaluated during risk assessment and carginogenic screening levels have been determined for some metals.

The EPA Region 6 Screening Levels were developed jointly with DOE's Oak Ridge National Laboratory (ORNL) under an Interagency Agreement as an update of the EPA Region 3 RBC Table, Region 6 HHMSSL Table and the Region 9 PRG Table.

Both As and Cd presented in Table 2 are known human carcinogens and have established carcinogenic SLs. The carcinogenic USEPA SLs for As residential and industrial exposures are 0.67 mg/kg and 3.0 mg/kg, respectively (using a target cancer risk of 1E-06). The residential carcinogenic SL for Cd is 2,100 mg/kg while the industrial carcinogenic

Table 2. Comparison of background median metal concentrations and ranges of Oklahoma benchmark soils with USEPA Region 6 Screening Level (SL) for residential and industrial exposures.

Trace Element	*Median Oklahoma Soil Levels (mg /kg)*	*Noncarcinogenic Residential SL*† *(mg/kg)*	*Noncarcinogenic Industrial SL (mg/kg)*
Arsenic (As)	3.96 (0.75-33.6)	34	380
Cadmium (Cd)	0.19 (0.13-0.80)	70	980
Chromium (Cr)	20.0 (4.30-69.7)	Not listed	Not listed
Copper (Cu)	11.1 (1.94-32.7)	3,100	47,000
Manganese (Mn)	439 (27.4-2165)	1,800	26,000
Molybdenum (Mo)	0.48 (0.18-1.80)	390	5,800
Nickel (Ni)	14.8 (2.41-57.3)	1,500	22,000
Lead (Pb)	13.5 (2.60-31.7)	400	800
Selenium (Se)	<1.25	390	5,800
Zinc (Zn)	52.4 (15.3-142)	23,000	350,000

† Obtained from USEPA Region 6 Regional Screening Levels (Hazard Index = 1) (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm).

SL is 9,300 mg/kg. Notice the background levels of the trace elements listed in Table 2 are considerably less than the residential SL with the exception of As. However, the mean background level of arsenic found in Oklahoma soils is approximately six times greater than the residential SL of 0.67 mg/kg established by the USEPA. The relatively high level of As in Oklahoma soils is probably due to naturally occurring high levels of As in geologic parent materials. It appears the regional SLs established for As are too low for Oklahoma soils and that background levels may be a useful alternative for baseline screenings and other risk assessments. Additionally, the use of background levels in these situations may eliminate the burden of unneeded soil remediation. Currently, the ODEQ recommends that uncontaminated samples be obtained in the area of the site under study and analyzed to determine background level of As that may be used as the screening level (ODEQ, personal communication).

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