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Similarities and differences in PM_{10} chemical source profiles for geological dust from the San Joaquin Valley, California

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Abstract

A systematic sampling and analysis approach was followed to acquire chemical source profiles for six types of geological dust in California's San Joaquin Valley. Forty-seven samples from 37 locations included: (1) urban and rural paved roads, (2) residential and agricultural unpaved roads and parking areas, (3) almond, cotton, grape, safflower, and tomato fields, (4) dairy and feedlot surfaces, (5) salt-laden lake and irrigation canal drainage deposits, and (6) building and roadway construction/earthmoving soil. These samples were dried, sieved, resuspended, sampled through a PM_{10} inlet onto filters, and chemically analyzed to construct PM_{10} source profiles (fractional mass abundances and uncertainties) for 40 elements (Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Rb, Sr, Y, Zr, Mo, Pd, Ag, Cd, In, Sn, Sb, Ba, La, Au, Hg, Tl, Pb, and U), 7 ions (Cl , NO_3 , PO_4^2 , SO_4^2 , Na^+, K^+, and NH_4^+), organic and elemental carbon (OC and EC), 8 carbon fractions (OC1, OC2, OC3, OC4, OP, EC1, EC2, and EC3), and carbonate carbon. Individual source profiles with analytical precisions were averaged and compared to quantify differences in chemical abundances for: (1) duplicate laboratory resuspension sampling, (2) multiple sampling within the same agricultural field, (3) sampling at different locations for the same land-use activity, (4) sampling of different activities regardless of location, and (5) grouping of different activities into generalized emission inventory source categories. Distinguishing features were found among composite source profiles of six source types. Elemental carbon and Pb marked paved road dust; Na^+, Na, S, and SO_4^2 marked salt deposits; OC, PO_4^2 , P, K^+, K, and Ca characterized animal husbandry; and several metals (Ti, V, Mn) marked construction soil, with abundances 2–10 times higher than those of other profiles. High-sensitivity X-ray fluorescence analysis resulted in detectable alkali and rare earth elements. Ga, Zr, Sn, and Ba were found in some of the paved road dust profiles; toxic species such as As, Mo, Cd, Sb, and U were found in salt deposits from canal drainage; and Pd, Rb, Sr, and Tl were found in construction dust. The profile-compositing methodology can be used for evaluating similarities and differences for other source characterization studies.

Keywords: Source profile; Geological dust; Paved and unpaved road dust; Agricultural soil

1. Introduction

Fugitive dust is a major contributor to PM_{10} (particles with aerodynamic diameters $<10\,\mu m$) and an important contributor to $PM_{2.5}$ (particles with aerodynamic diameters $<2.5\,\mu m$) during the summer and fall in California's San Joaquin Valley (SJV) (Chow et al., 1992, 1993a). SJV fugitive dust is believed to originate from paved and unpaved roads and parking lots, agricultural field preparation, cultivation, harvesting, wind erosion of fallow land, and construction of buildings and roadways. Fugitive dust emissions are

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intermittent and highly variable; consequently, source-oriented air quality models applied to annual emissions inventories are of limited use for determining the cause of large contributions to PM_{10} and $PM_{2.5}$. Receptor models use measured elemental, ionic, and carbonaceous fractions of total mass (F_{ij}) for species i from source j to separate fugitive dust contributions at receptors from other source types in the SJV (Chow et al., 1992; Magliano et al., 1999; Schauer and Cass, 2000) and elsewhere (Chow and Watson, 2002a).

Because many of these chemical components are common to all fugitive dust emitters, and because each F_{ij} has an uncertainty (σ_{ij}, determined from the larger of the standard deviation of F_{ij} for several representative samples or the analytical precision), the commonly quantified elements, ions, and carbon fractions are often insufficient to distinguish among different fugitive dust emitters. Only a limited number of source profiles can be measured owing to the complexity and costs of field sampling, resuspension, chemical analysis, data validation, and data interpretation. The question always arises: How many fugitive dust source samples are needed to represent the large number of individual emitters that contribute to ambient concentrations? Individual source profiles (from a single sample) and/or composite source profiles (averages of individual profiles) have been used as input to the Chemical Mass Balance (CMB) receptor model (Watson et al., 1984, 1991) with little or no rationale given about how well these represent contributors. Previous fugitive dust sampling and profile-compositing methods have not systematically examined the differences among and between samples from different source activities and locations, nor have they systematically extended analyses to more exotic chemical and physical markers.

The central California Fugitive Dust Characterization Study (FDCS, Watson et al., 1997; Ashbaugh et al., 2002) was undertaken to determine the extent to which systematic sampling and enhanced chemical characterization might improve the discrimination of fugitive dust subtypes from each other. The FDCS obtained 47 separate fugitive dust samples during 1997 from representative emission activities and SJV locations in sufficient quantity that a variety of physical and chemical analyses could be applied. Specific organic compounds (pesticides, herbicides, cellulose, etc.), DNA, toxins, bioaerosols (microbes, bacteria), and particle size and morphology were measured by different laboratories and will be reported in subsequent publications (Watson et al., 1997). Elemental, ionic, and fractional carbon abundances are reported here with the following extensions: (1) detectable levels and higher precisions for many of the transition metals achieved with high-sensitivity X-ray fluorescence (XRF); (2) water-soluble phosphate (PO_4^{2-}), sodium (Na^+), potassium (K^+), and ammonium (NH_4^+), (3) eight thermally evolved carbon fractions, and (4) carbonate carbon.

Several performance measures are examined here to evaluate similarities and differences among source profiles at various levels of grouping into composite profiles. These composites are intended to represent mass fractional abundances, and the uncertainties of those abundances, for species in a larger population. The compositing framework is applicable to additional chemical and physical measurements of source materials. Specific objectives are to: (1) document geological source profiles acquired by the FDCS, (2) quantify sampling and analysis variabilities, (3) examine similarities and differences among dust emitters within and between source types, and (4) develop source profiles useful for receptor modeling and speciated PM emission inventories.

2. Methods

Potential dust emitters in the SJV were identified and sampled based on available emission inventories and results from previous studies (Watson et al., 1997): (1) paved road dust from urban and rural areas; (2) unpaved road and shoulder dust from agricultural and residential roads and from agricultural staging areas; (3) agricultural soil (after harvesting and land preparation) from five widely cultivated SJV crops—almond, cotton, grape, safflower, and tomato; (4) animal husbandry soil from dairies and feedlots; (5) deposits from a dry lake bed and irrigation canal drainage with apparent salt buildup; and (6) building and roadway construction/earthmoving soil.

Sufficient quantities (~0.5–1 kg) of 47 geological samples (with the exception of a Fresno county paved road dust) were dried at 105°C, sieved through a Tyler 200 mesh screen (75 μm geometric diameter), suspended in a chamber, and sampled through size-selective inlets onto filters suitable for chemical analysis (Carvacho et al., 1996; Ashbaugh et al., 2002). Clean air was pulsed through a fluidized bed of the sieved material in a vertical flow (6 cm s^{-1}) to churn and suspend particles (typically $<\sim$40 μm aerodynamic diameter) into a 90-l dust collection chamber. Air was drawn from an Andersen SA246 PM_{10} inlet (Graseby Andersen, Smyrna, GA) at 16.7 l min^{-1} through an IMPROVE sampler. Sampling times of ~75 s resulted in 0.1–2.0 mg particle loadings on 47 mm Teflon-membrane and quartz-fiber filters.

Teflon-membrane filters were analyzed for mass by gravimetry and for 40 elements by high-sensitivity XRF (Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, As, Se, Br, Rb, Sr, Y, Zr, Mo, Pd, Ag, Cd, In, Sn, Sb, Ba, La, Au, Hg, Tl, Pb, U) (Watson et al., 1999). Mass was also measured on the quartz filter by

Table 1
Summary of geological samples acquired in California's San Joaquin Valley

Source type	Total number of samples	Number of samples by county					
		Merced	Madera	Fresno	Tulare	Kings	Kern
Paved road dust							
Urban streets	1						
Non-urban streets	2				1		1
Unpaved road dust							
Agricultural roads	3			1		1	1
Public/residential roads	3					2	1
Staging soil	1					1	
Agricultural soil							
Almond orchard	6	1		1[a]			4
Cotton field	12			6[a]		2	4
Grape vineyard	3		1	2			
Safflower field	3					1	2
Tomato field	5			5			
Animal husbandry							
Dairy	2			1	1		
Feedlot	2			1			1
Disturbed soil							
Construction/earthmoving dust	2		1	1			
Salt build-up area	2					1	1
Total	47	1	2	18	2	8	16

[a] Replicate resuspension sampling was conducted.

gravimetry. Half of the quartz-fiber filter was extracted in deionized distilled water and analyzed for chloride (Cl^-), nitrate (NO_3^-), PO_4^{2-}, and sulfate (SO_4^{2-}) by ion chromatography (Chow and Watson, 1999); for NH_4^+ by automated colorimetry; and for Na^+ and K^+ by atomic absorption spectrophotometry. A 0.5 cm^2 punch from the remaining half filter was analyzed for eight carbon fractions following the IMPROVE thermal/optical reflectance (TOR) protocol (Chow et al., 1993b, 2001; Chow and Watson, 2002b; Fung et al., 2002). This produced four organic carbon (OC) fractions (OC1, OC2, OC3, and OC4 at 120°C, 250°C, 450°C, and 550°C, respectively, in a helium atmosphere), a pyrolyzed carbon fraction (OP, determined when reflected laser light attained its original intensity after oxygen was added to the combustion atmosphere), and three elemental carbon (EC) fractions (EC1, EC2, and EC3 at 550°C, 700°C, and 800°C, respectively, in a 2% oxygen/98% helium atmosphere). The carbonate carbon abundance was determined by acidification of the sample prior to thermal analysis with subsequent detection of the evolved CO_2. The IMPROVE protocol does not achieve sufficient temperatures to thermally decompose calcium carbonate (Chow and Watson, 2002b). IMPROVE OC is operationally defined as OC1 + OC2 + OC3 + OC4 + OP and EC is defined as EC1 + EC2 + EC3 − OP. Other thermal analysis carbon protocols do not necessarily yield comparable OC and EC fractions.

The 47 individual source profiles, categorized by SJV county, are specified in Table 1 with greater detail on the measurement locations and soil characteristics in Ashbaugh et al. (2002). Averages and standard deviations of the chemical abundances from subsets of these profiles are intended to represent a larger population of similar sources. Fig. 1 diagrams the hierarchical approach to this compositing that is applied here, with each successive level representing a larger number of profiles in the group but a lower commonality among the sampling locations and source categories. Level I examines similarities between duplicate resuspension profiles from the same bulk sample. Level II compares abundances in different profiles from the same locations for several agricultural fields. Level III tests for profile differences among similar activities at different locations in the SJV. Level IV compares profiles derived from different activities, regardless of location. Level V groups specific activities into generalized emission

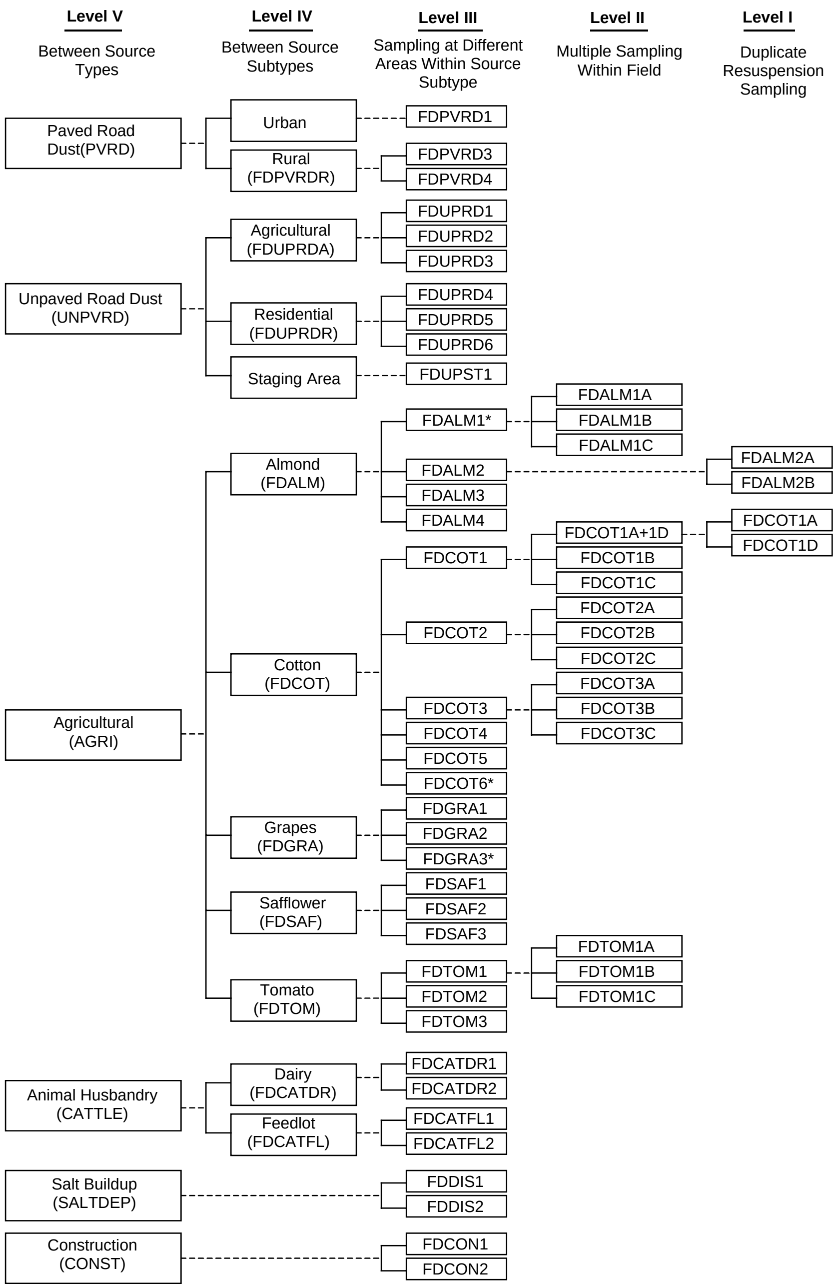


Fig. 1. Source profile-compositing scheme for testing within sources and between source variabilities. Source profile mnemonics for Levels IV and V are in parentheses. (A* indicates profiles eliminated at Level III from further composites.)

inventory categories of paved and unpaved road dust, agricultural crops, animal husbandry, salt-laden playas, and construction, then examines similarities and differences that might allow these source contributions to be distinguished from each other. All individual and intermediate composite profiles are available in electronic form from the authors.

Three performance measures are used to quantify similarities and differences among profile pairs: (1) the Student *t*-test estimates the statistical significance of differences between chemical abundances, (2) the correlation coefficient (r) between the F_{ij} divided by σ_{ij} quantifies the strength of association between profiles, and (3) the distribution of weighted differences [residual(R)/uncertainty(U) = $(F_{i1} \quad F_{i2})/(\sigma_{i1}^2 + \sigma_{i2}^2)^{0.5}$] shows how many of the chemical abundances differ by multiples of the uncertainty of the difference. The variance (r^2) and the R/U ratio are CMB performance measures (Watson et al., 1998) that quantify the agreement between measured receptor concentrations and those produced by the source profiles and source contribution estimates.

For the t-test, a probability level of 5% is selected as a similarity cutoff; if $P<0.05$, there is a 95% probability that the profiles are different. For the correlation coefficients, $r>0.8$ indicates similar profiles, $0.5<r<0.8$ indicates a moderate similarity, and $r<0.5$ indicates little or no similarity. The R/U ratio indicates how many of the 59 reported chemical abundances differ by more than an expected number of uncertainty intervals. The normal probability density function of 68%, 95.5%, and 99.7% for $\pm1\sigma$, $\pm2\sigma$, and $\pm3\sigma$, respectively, is used to evaluate the R/U ratios. The number of species abundances within each range and $>3\sigma$ is tabulated; when 80% of the R/U ratios are within $\pm3\sigma$, with $r>0.8$ and $P>0.05$, the two profiles are considered to be similar, within the uncertainties of the chemical abundances. Abundances with R/U ratios >3 are discussed separately as these may be markers that further allow source contributions to be distinguished by receptor measurements. They may also be real artifacts of the sampling and analysis process and not representative of the larger population of source profiles.

3. Results and discussion

3.1. Similarities and differences among profiles

Performance measures for the different profile composites illustrated in Fig. 1 are summarized in Table 2. For two duplicate resuspensions from the same bulk soil sample, all performance measures should show the profiles to be similar at Level I. This is the case for replicates from Almond Field 2 (FDALM2A&B) and Cotton Field 1 (FDCOT1A&D). Correlation coefficients exceed 0.98 and $P>0.05$. More than 95% of the R/U ratios show differences between paired abundances within $\pm3\sigma\cdot$ Only analytical precisions are used for the individual profiles, and for most species the differences between resuspensions of different portions of the same sample are within a reasonable number of reported analytical precision intervals. For the almond profile comparison, R/U ratios exceeded 6 for Sr and Pb. For Sr, the abundances were $0.039\pm0.0007\%$ for FDALM2A and $0.034\pm0.0005\%$ for FDALM2B, indicating that the real uncertainty exceeds the analytical precision estimate. For Pb, however, the abundances differ by more than an order of magnitude, with $0.0010\pm0.0017\%$ for FDALM2A and $0.0133\pm0.008\%$ for FDALM2B. This could have occurred if a small speck of Pb were in one portion of the bulk sample but not in the other, a possibility that might have occurred when leaded fuel was used in farm equipment. This illustrates one of the cautions when using non-native additives as source markers; they may not be uniformly applied or mixed throughout the surface material. For the cotton field, the Zn R/U ratio was 3.2, only slightly larger than the 3σ criterion. Averages of the replicate suspension profiles are used in subsequent comparisons.

The Level II comparison is for different samples from the same source area. Each sample is a mixture of smaller samples taken from several locations within each agricultural field, but the locations for these smaller samples were not replicated for each bulk sample. Source profile uncertainties are expected to be higher than analytical precisions, but not appreciably so. There should be no significant differences between profiles if these are intended to represent all of the dust suspended from the sampled field. Table 2 shows that all of the Level II profiles have correlation coefficients exceeding 0.9. Only the FDCOT2A&C and FDCOT3A&C comparisons have $P<0.05$, but not by very much (0.03). More than 95% of the differences are within $\pm3\sigma$ except for the FDCOT1B&C and FDTOM1A&B comparisons. A single sample from each field would have been sufficient to represent most chemical abundances from these individual fields, and the analytical precision reasonably estimates the variability of that sample. Chemicals with R/U ratios >3 in one or more of the comparisons were Na, Mg, Mn, Fe, Cu, Zn, Ga, and Sr. Most of these differences occur because the analytical uncertainty is better than the natural variability in abundances from different samples. The large R/U ratio of 6.8 for Fe in the FDCOT1B&C comparison corresponded to abundances of $5.4\pm0.08\%$ and $4.3\pm0.15\%$, respectively. The actual difference is within expectations for soil mineralogical contents. The largest R/U ratio is 12 for Sr in the FDTOM1A&B comparison, even though the two abundances differ by only $\sim20\%$. Sr is very reproducible by XRF, with a $\sim2\%$ analytical coefficient of variation. Analytical uncertainties on individual samples for these species underestimate their natural variability, even with samples from the same source location. Ga was detected at $0.0024\pm0.0005\%$ in FDTOM1A but not at all in FDTOM1B. A single sample from this field might give the impression that Ga is a good marker for tomato crops, when it is more probable that a small speck of inhomogeneously distributed ore was found in only one of the samples. The Ga abundance is less than detection limits in nearly all of the other fugitive dust samples.

For Level III comparisons, individual profiles are grouped by source subtype and sampling location. It is expected that chemical abundances will be more variable

Table 2
Statistical measures of the variability in geological dust

Composite level	Profile mnemonic		Percent distribution[a]				Correlation coefficient (r)	t-statistic[b]; P value
	Profile#1	Profile#2	$<1\sigma$	$1\sigma-2\sigma$	$2\sigma-3\sigma$	$>3\sigma$		
Level I—Variations due to duplicate resuspension sampling								
	Almond vs. almond							
	FDALM2A	FDALM2B	72%	19%	3%	5%	0.98	0.51
	Cotton vs. cotton							
	FDCOT1A	FDCOT1D	80%	15%	3%	2%	0.98	0.14
	Level I summary		76%	17%	3%	3%		
Level II—Variations due to multiple sampling within an agricultural field								
	Almond vs. almond							
	FDALM1A	FDALM1B	97%	3%	0%	0%	0.98	0.19
		FDALM1C	86%	8%	2%	3%	0.98	0.23
	FDALM1B	FDALM1C	81%	12%	2%	5%	0.95	0.75
	Cotton vs. cotton							
	FDCOT1A + 1D	FDCOT1B	88%	2%	8%	2%	0.94	0.081
		FDCOT1C	81%	10%	5%	3%	0.94	0.74
	FDCOT1B	FDCOT1C	76%	14%	2%	8%	0.96	0.11
	FDCOT2A	FDCOT2B	90%	7%	2%	2%	0.95	0.45
		FDCOT2C	71%	14%	10%	5%	0.93	0.033
	FDCOT2B	FDCOT2C	67%	26%	3%	3%	0.99	0.12
	FDCOT3A	FDCOT3B	78%	17%	2%	3%	0.99	0.55
		FDCOT3C	83%	14%	2%	2%	0.94	0.035
	FDCOT3B	FDCOT3C	83%	12%	2%	3%	0.97	0.070
	Tomato vs. tomato							
	FDTOM1A	FDTOM1B	78%	7%	3%	12%	0.99	0.85
		FDTOM1C	76%	14%	5%	5%	0.99	0.39
	FDTOM1B	FDTOM1C	76%	16%	5%	3%	0.99	0.48
	Level II summary		81%	12%	4%	4%		
Level III—Variations within source subtype								
	Rural paved road dust vs. rural paved road dust							
	FDPVRD3	FDPVRD4	69%	10%	3%	17%	0.96	0.83
	Unpaved road dust vs. unpaved road dust							
	Agricultural FDUPRD1	Agricultural FDUPRD2	64%	12%	7%	17%	0.64	0.014
		Agricultural FDUPRD3	61%	14%	4%	21%	0.92	0.028
	Agricultural FDUPRD2	Agricultural FDUPRD3	68%	12%	12%	7%	0.64	0.77
	Residential FDUPRD4	Residential FDUPRD5	74%	16%	5%	5%	0.81	0.0091
		Residential FDUPRD6	71%	10%	5%	14%	0.92	0.19
	Residential FDUPRD5	Residential FDUPRD6	72%	3%	12%	12%	0.88	0.042
	Almond vs. almond							
	Field 1 FDALM1*	Field 2 FDALM2	64%	10%	8%	17%	0.59	0.033
		Field 3 FDALM3	72%	10%	10%	7%	0.69	0.63
		Field 4 FDALM4	76%	9%	12%	3%	0.66	0.44
	Field 2 FDALM2	Field 3 FDALM3	79%	9%	5%	7%	0.77	0.06
		Field 4 FDALM4	79%	12%	3%	5%	0.82	0.10
	Field 3 FDALM3	Field 4 FDALM4	83%	10%	3%	3%	0.97	0.76
	Cotton vs. cotton							
	Field 1 (FDCOT1)	Field 2 FDCOT2	84%	7%	2%	7%	0.89	0.80
		Field 3 FDCOT3	71%	21%	5%	3%	0.78	0.17
		Field 4 FDCOT4	72%	12%	9%	7%	0.78	0.0084
		Field 5 FDCOT5	81%	5%	3%	10%	0.74	0.050
		Field 6 FDCOT6*	74%	9%	5%	12%	0.81	0.0023
	Field 2 FDCOT2	Field 3 FDCOT3	88%	3%	3%	5%	0.70	0.13
		Field 4 FDCOT4	84%	7%	5%	3%	0.80	0.0074

Table 2 (*continued*)

Composite level	Profile mnemonic		Percent distribution[a]				Correlation coefficient (r)	t-statistic[b]; P value
	Profile#1	Profile#2	$<1\sigma$	$1\sigma-2\sigma$	$2\sigma-3\sigma$	$>3\sigma$		
	Field 2 FDCOT2	Field 5 FDCOT5	81%	16%	2%	2%	0.79	0.042
		Field 6 FDCOT6*	77%	9%	7%	7%	0.82	0.002
	Field 3 FDCOT3	Field 4 FDCOT4	83%	12%	2%	3%	0.91	0.033
		Field 5 FDCOT5	79%	12%	2%	7%	0.90	0.26
		Field 6 FDCOT6*	70%	9%	9%	12%	0.85	0.015
	Field 4 FDCOT4	Field 5 FDCOT5	71%	12%	5%	12%	0.93	0.19
		Field 6 FDCOT6*	61%	7%	2%	30%	0.93	0.97
	Field 5 FDCOT5	Field 6 FDCOT6*	67%	14%	5%	14%	0.86	0.15
	Grape vs. grape							
	Field 1 FDGRA1	Field 2 FDGRA2	61%	18%	9%	12%	0.98	0.88
		Field 3 FDGRA3*	68%	11%	5%	16%	0.98	0.82
	Field 2 FDGRA2	Field 3 FDGRA3*	71%	9%	5%	16%	0.97	0.92
	Safflower vs. safflower							
	Field 1 FDSAF1	Field 2 FDSAF2	81%	14%	3%	2%	0.89	0.0047
		Field 3 FDSAF3	79%	10%	10%	0%	0.87	0.0016
	Field 2 FDSAF2	Field 3 FDSAF3	72%	19%	2%	7%	0.94	0.32
	Tomato vs. tomato							
	Field 1 FDTOM1	Field 2 FDTOM2	66%	22%	2%	10%	0.81	0.059
		Field 3 FDTOM3	84%	10%	5%	0%	0.80	0.16
	Field 2 FDTOM2	Field 3 FDTOM3	79%	12%	3%	5%	0.93	0.013
	Animal husbandry vs. animal husbandry							
	Dairy FDCATDR1	Dairy FDCATDR2	71%	12%	2%	16%	0.67	0.074
	Feedlot FDCATFL1	Feedlot FDCATFL2	53%	17%	9%	21%	0.94	0.10
	Disturbed soil vs. disturbed soil							
	Salt Buildup FDDIS1	Salt Buildup FDDIS2	66%	16%	7%	12%	0.94	0.36
	Construction site soil vs. construction site soil							
	Construction FDCON1	Construction FDCON2	76%	19%	5%	0%	0.91	0.0079
	Level III summary		73%	12%	5%	9%		
Level IV—Variations between source subtypes								
	Paved road dust							
	Urban FDPVRD1	Rural FDPVRDR	64%	24%	9%	3%	0.75	0.18
	Unpaved road dust							
	Agricultural FDUPRDA	Residential FDUPRDR	95%	5%	0%	0%	0.88	0.62
		Staging area FDUPST1	81%	17%	2%	0%	0.74	0.0022
	Residential FDUPRDR	Staging area FDUPST1	74%	26%	0%	0%	0.77	0.0028
	Agricultural soil							
	Almond FDALM	Cotton FDCOT	90%	10%	0%	0%	0.76	0.47
		Grape FDGRA	90%	7%	2%	2%	0.80	0.84
		Safflower FDSAF	98%	0%	2%	0%	0.89	0.42
		Tomato FDTOM	86%	9%	2%	3%	0.88	0.72
	Cotton FDCOT	Grape FDGRA	88%	10%	2%	0%	0.94	0.30
		Safflower FDSAF	93%	7%	0%	0%	0.83	0.88
		Tomato FDTOM	95%	5%	0%	0%	0.81	0.25
	Grape FDGRA	Safflower FDSAF	90%	9%	2%	0%	0.84	0.26
		Tomato FDTOM	83%	14%	3%	0%	0.79	0.86
	Safflower FDSAF	Tomato FDTOM	91%	9%	0%	0%	0.81	0.22
	Animal husbandry							
	Dairy FDCATDR	Feedlot FDCATFL	80%	17%	2%	2%	0.49	0.29
	Level IV summary		86%	11%	2%	1%		
Level V—Variations between source types								
	Paved road dust PVRD	Unpaved road dust UNPVRD	93%	7%	0%	0%	0.48	0.29
		Agricultural AGRI	98%	2%	0%	0%	0.59	0.22
		Animal husbandry CATTLE	75%	24%	2%	0%	0.67	0.35
		Salt buildup SALTDEP	76%	19%	2%	3%	0.49	0.90

Table 2 (*continued*)

Composite level	Profile mnemonic		Percent distribution[a]				Correlation coefficient (r)	t-statistic[b]; P value
	Profile#1	Profile#2	$<1\sigma$	$1\sigma-2\sigma$	$2\sigma-3\sigma$	$>3\sigma$		
	Paved road dust PVRD	Construction CONST	86%	9%	2%	3%	0.78	0.77
	Unpaved road dust UNPVRD	Agricultural AGRI	100%	0%	0%	0%	0.94	0.79
		Animal husbandry CATTLE	76%	17%	7%	0%	0.55	0.90
		Salt Buildup SALTDEP	91%	5%	2%	2%	0.62	0.18
		Construction CONST	88%	12%	0%	0%	0.71	0.36
	Agricultural AGRI	Animal husbandry CATTLE	76%	15%	8%	0%	0.60	0.65
		Salt buildup SALTDEP	86%	9%	3%	2%	0.66	0.13
		Construction CONST	93%	5%	2%	0%	0.77	0.27
	Animal husbandry CATTLE	Salt buildup SALTDEP	69%	19%	10%	2%	0.56	0.21
		Construction CONST	62%	24%	10%	3%	0.75	0.42
	Salt buildup SALTDEP	Construction CONST	81%	14%	3%	2%	0.70	0.65
	Level V summary		83%	12%	3%	1%		

[a] Fraction of chemical abundances that differ by less than multiples of the precision of the difference as determined from residual/uncertainty (R/U) ratios. $R/U = (F_{i1} — F_{i2})/(\sigma_{i1}^2 + \sigma_{i2}^2)^{0.5}$.

[b] A value <0.05 indicates that there is less than a 5% probability that the profiles were drawn from the same population.

*Indicates profile eliminated at Level III from further composites.

for the same activity sampled at different locations because the basic soil characteristics may differ. Table 2 shows that a larger number of samples differ by more than analytical precisions for several species, but there is still substantial similarity between the profiles. The fraction of comparisons with $r>0.8$ declined from 100% for Levels I and II to 71% for Level III comparisons. Even though 93% of species differences fall within $\pm 3\sigma$, overall, Table 2 shows that ~40% of the profiles are statistically different with $P<0.05$. For the two rural paved road dust profiles, the Tulare county (FDPVRD4) profile shows 19% higher OC, 38% lower carbonate carbon, 20% lower Al, 10% lower Si, twice the Ca, 13% lower Fe, 73% lower Zn, 13% lower Ba, and twice the La compared to the Kern county (FDPVRD3) paved road dust profile. Seventeen percent of the chemical abundances differ by more than $\pm 3\sigma$, even though the t-test indicates no statistical difference. The R/U ratio is the best indicator of major differences, and an examination of individual R/U ratios > 3 shows which species abundances are the most variable.

There are large within-group (source subtype) differences among the three agricultural unpaved road dust profiles (FDUPRD1, 2, and 3) from Fresno, Kings, and Kern counties with low correlations ($r = 0.6$) between the Fresno (FDUPRD1) and Kings (FDUPRD2) county profiles. Carbonate carbon, Al, Si, and Ca abundances differ by more than their uncertainties in these profiles. Part of this is due to different mineral contents in the soils. Lower Al (3.5±1.1%) and Si (15.0±5.0%) abundances in FDUPRD2 are offset by higher Ca (8.5±1.6%) and carbonate carbon (2.1±0.2%) abundances relative to the other samples. Similar differences are found among the three residential unpaved road dust profiles (FDUPRD4, 5, and 6) from Kings and Kern counties, with four- to six-fold differences in OC4, carbonate carbon, and Ca abundances. The distribution of differences shows that 79–93% and 86–95% of chemical abundances are within $\pm 3\sigma$ for the agricultural and residential unpaved road profiles, respectively.

The central Kern county FDALM1 profile derived from three separate samples differs from profiles of other almond fields, with $0.59<r<0.69$. OC is 4–5 times more abundant, whereas Si is 21–29% lower and Ca is 17–63% higher in FDALM1 relative to the other three almond field profiles. The carbonate carbon abundance is 0.19±0.10% in Fresno county FDALM2 sample, much lower than the 3.2±1.8% abundance in the Merced county FDALM4 sample. Ashbaugh et al. (2002) show that soil from the Kern county almond field (FDALM1) has the highest carbon and nitrogen content with low (10–12%) clay content. The three almond orchard profiles from Fresno, Western Kern, and Merced counties (FDALM2, 3, and 4) are combined (FDALM) to compare with the central Kern county almond profile (FDALM1). Removing FDALM1 increases the fraction of differences within $\pm 1\sigma$ from 78% to 97%, so the FDALM1 profile is eliminated from further almond composites.

The 12 samples from six cotton fields have similar profiles, with the exception of FDCOT6. This sample, acquired from the west side of Kings county, contains 6–14 times higher Ca (17.9±2.9%), 3–8 times higher OC4 (2.9±0.4%), 1–3 times higher OC (4.8±0.6%), and 2–6 times higher Sr (0.09±0.0013%) abundances than the other profiles. The abundance of Al (7.5±2.2%) in FDCOT6 is 21–45% lower than those for the other cotton profiles. Abundances of Si differ ~30% from 27.6±8.6% in FDCOT6 to 35.9±11.3% in FDCOT3. Ashbaugh et al. (2002) show the FDCOT6 sample having the lowest sand content (6.4%), highest clay content (85.2%), and highest silt loading (93.6%) of all the soils sampled. The R/U ratios between the cotton composite (FDCOT1+2+3+4+5) and FDCOT6 show large differences ($5-7\sigma$) between OC4, Ca, and Sr abundances. Abundances differ by $1\sigma-2\sigma$ for Na^+, Na, K^+, OC, carbonate carbon, Ti, and Mn. Comparisons of five individual cotton profiles (FDCOT1, 2, 3, 4, and 5) with the cotton composite (FDCOT) result in 88–100% $<\pm1\sigma$, with the remaining 0–12% between $\pm1-2\sigma$. FDCOT6 is eliminated from further cotton composites.

Grape field profiles from eastern Fresno county (FDGRA3) contain 33–36% lower Al, 23–38% lower Si, 25–45% lower K, 14–56% lower Ca, and 44–49% lower Fe than the other two vineyard profiles. Sand content (83.8%) for FDGRA3 soil is 11–18% higher than that for soils from the other two grape field samples with very low clay (3.8%) content (Ashbaugh et al., 2002). Even though correlations ($r>0.97$) are high among the three vineyard profiles, only 61–71% of the differences are within $\pm1\sigma$. Uncertainties are reduced by 6–7% when FDGRA3 is removed from the composite.

There are large differences among the three safflower profiles. OC and Al abundances are similar for the two southern Kern county (FDSAF2&3) profiles. The OC (2.7±0.36% in FDSAF3 to 6.4±2.9% in FDSAF1) and carbonate carbon (0.2±0.1% in FDSAF3 to 3.1±1.1% in FDSAF1) abundances are substantially different. Removing any single profile does not improve the R/U ratio or change the t-test probability. These three profiles are combined (FDSAF), resulting in larger uncertainties than for most of the other profiles.

The five samples from three tomato fields have similar chemical abundances, with 24–28% higher Al and 11–15% higher Si in northwestern Fresno county profile (FDTOM1) than in profiles from southern (FDTOM2) and western (FDTOM3) parts of the county. More than 90% of the differences are within $\pm3\sigma$ with high correlations ($0.80<r<0.93$).

The feedlot profile from western Fresno county (FDCATFL2) contains 80% higher OC and TC, ~46% lower Al, 37% lower Si, 2.4 times higher P, and 1.5 times higher Ca than the profile from southern Kern county (FDCATFL1). The t-tests show no statistically significant differences, and $r=0.94$. Nevertheless, 21% of the R/U ratios exceed 3, indicating a large number of differences in chemical abundance that exceed the analytical precisions of the individual profiles. The Fresno county dairy profile (FDCATDR2) contains 75% higher OC, 3 times higher EC, and 15% higher Si than the Tulare county profile (FDCATDR1). Although the t-test probability criterion is achieved, these profiles are only moderately correlated ($r=0.67$) and 16% of the R/U ratios exceed 3. A larger number of samples from these source types is needed to determine the uncertainties of the chemical abundances.

The two salt deposit profiles are similar according to the t-test, highly correlated ($r=0.94$), with 88% of the differences within $\pm3\sigma$. The Na^+ abundances are 1.6±0.14% for the Kern Lake ranch (FDDIS2) profile and 2.9±0.4% for the Tulare Lake drainage district profile in Kings county (FDDIS1). The FDDIS1 profile contains 2–3 times higher S, 28% lower Cl, 30% lower Ca, and 21% lower Fe than the FDDIS2 profile.

The two construction/earthmoving profiles from Fresno and Madera counties are dissimilar according to the t-test, but highly correlated ($r=0.91$), with 19% higher Al, 19% higher Si, and 38% higher Ca in the Madera county building construction profile (FDCON2) than in the Fresno county roadway construction profile (FDCON1). None of the R/U ratios exceed 3, indicating agreement for all species abundances within the analytical precisions.

The Level IV composites account for activity as well as location-related differences. The 14 Level IV profiles show R/U ratios within ±3 for >98% of the paired comparisons, with 86% of the differences within ±1. Correlations are 5–10% lower than those for Level III, with $r=0.75$ for the urban vs. rural paved road profiles, $0.74<r<0.88$ for the agricultural and residential unpaved road dust vs. agricultural staging area profiles, and $0.76<r<0.94$ for the five agricultural field profiles. The lowest correlation ($r=0.49$) occurs for the feedlot vs. dairy profile comparison. The t-test shows dissimilarities between the staging area (FDUPST1) and both the agricultural (FDUPRDA) and residential (FDUPRDR) unpaved road dust profiles. Due to the limited number of samples available, these source subtypes are further grouped into six profiles by source type.

For the Level V profiles that define major emission inventory categories, the uncertainties of chemical abundances are often higher than at other levels, as expected. These higher uncertainties are the main cause of most R/U ratios being <3. Most of the paired correlations are lower ($0.5<r<0.8$) than those for the other levels, indicating substantial dissimilarity. The only high correlation ($r=0.94$) was found between the composited unpaved road dust (UNPVRD) and agricultural soil (AGRI) profiles. The lowest correlations were found between the paved road dust (PVRD) and unpaved road dust (UNPVRD) profiles ($r=0.48$) and between the paved road dust (PVRD) and salt buildup (SALTDEP) profiles ($r=0.49$). None of the Level V t-test probabilities show a statistically significant difference between the profiles, however.

Table 3 summarizes the Level IV and V composite profiles and the six Level V source types are illustrated in

Table 3
Composite geological profiles[a] (in percent of PM_{10} mass) from the San Joaquin Valley, California

	Paved road dust			Unpaved road dust			
Mnemonic[b] Source type County	FDPVRD1 Urban Fresno	FDPVRDR Rural Kern /Tulare	PVRD Composite	FDUPRDA Agricultural Fresno/ Kings/ Kern	FDUPRDR Residential Kings /Kern	FDUPST1 Staging area soil Kings	UNPVRD Composite
Chloride (Cl^-)	0.0954±0.2220	0.11±0.1355	0.1027±0.1839	0.1326±0.1389	0.0546±0.1178	0.0861±0.0959	0.0911±0.1188
Nitrate (NO_3^-)	0±0.2204	0.0871±0.1321	0.0435±0.1817	1.0555±1.4987	0±0.117	0.1088±0.095	0.3881±0.8696
Phosphate (PO_4^{2-})	0±0.0000	0.0582±0.0823	0.0291±0.0582	0±0	0±0	0±0	0±0
Sulfate (SO_4^{2-})	0.3074±0.2290	0.25±0.1352	0.2787±0.1881	0.7321±0.3441	0.359±0.4148	0.3399±0.0988	0.477±0.3163
Ammonium (NH_4^+)	0.4272±0.2818	0.2193±0.1639	0.3233±0.2305	0.0955±0.0881	0.1309±0.1371	0.1341±0.1119	0.1202±0.1141
Soluble sodium (Na^+)	0.0869±0.0379	0.0708±0.032	0.0789±0.0351	0.3282±0.3398	0.0658±0.0328	0.1047±0.018	0.1662±0.1974
Soluble potassium (K^+)	0.148±0.0561	0.1538±0.1141	0.1509±0.0899	0.1269±0.0888	0.1143±0.0621	0.0442±0.0203	0.0951±0.0636
OC1	0.4671±0.3837	0.0821±0.172	0.2746±0.2973	0.0681±0.1047	0.1191±0.1744	0.2269±0.1602	0.138±0.1495
OC2	1.3117±0.5781	0.4559±0.2848	0.8838±0.6051	0.2681±0.1581	0.4015±0.2454	0.4822±0.2115	0.3839±0.2081
OC3	3.6049±1.5890	1.7359±0.8511	2.6704±1.3216	0.6862±0.4656	1.6049±0.7654	1.1725±0.6011	1.1545±0.6229
OC4	2.5477±0.7967	1.3664±0.3699	1.9571±0.8353	1.3796±1.123	1.9441±1.527	0.6208±0.2309	1.3148±1.1025
Pyrolyzed carbon (OP)	1.6007±0.6036	0.6175±0.5187	1.1091±0.6952	0.4561±0.4027	0.2895±0.2183	0±0.1709	0.2485±0.2823
Organic carbon (OC)	9.5322±2.5953	4.2578±1.0974	6.895±3.7295	2.8581±1.0813	4.359±2.1239	2.5024±0.7387	3.2399±1.4406
EC1	1.5795±0.5715	0.5767±0.3346	1.0781±0.7091	0.3495±0.2465	0.2745±0.1736	0.3746±0.1545	0.3329±0.1956
EC2	1.689±0.9471	0.3623±0.2817	1.0257±0.9381	0.2045±0.1553	0.1884±0.2142	0.3369±0.2249	0.2433±0.2005
EC3	0±0.0999	0±0.0597	0±0.0823	0±0.0338	0±0.053	0±0.0427	0±0.0439
Elemental carbon (EC)	1.6678±1.1784	0.3215±0.4597	0.9946±0.952	0.0979±0.2688	0.1734±0.3528	0.7115±0.3277	0.3276±0.3346
Total carbon (TC)	11.2±3.0696	4.5793±1.208	7.8896±4.6815	2.956±1.0999	4.5324±2.1121	3.2139±0.8245	3.5674±1.4549
Carbonate carbon (C in CO_3^{2-})	1.8728±0.6288	0.7473±0.5626	1.3101±0.5966	1.1985±0.2169	1.5919±0.4365	0.6949±0.2119	1.1618±0.3069
Sodium (Na)	0.1519±0.0502	0.1606±0.1057	0.1562±0.0828	0.3873±0.4129	0.15±0.1546	0.2124±0.0201	0.2499±0.2548
Magnesium (Mg)	0.7536±0.0427	0.8129±0.0597	0.7833±0.0519	0.6648±0.4256	0.8464±0.2224	1.2186±0.0201	0.9099±0.2823
Aluminum (Al)	7.9862±2.3696	12.0154±3.5443	10.0008±3.0147	9.0706±5.0928	10.811±3.2357	10.8431±3.1795	10.2416±3.9377
Silicon (Si)	23.4286±7.3732	32.904±10.3058	28.1663±8.9603	30.5722±13.5846	34.3955±10.9174	33.7781±10.5625	32.9153±11.7657
Phosphorus (P)	0.6382±0.2699	0.1372±0.0608	0.3877±0.3543	0.093±0.064	0.1262±0.0612	0.0359±0.0199	0.085±0.0524
Sulfur (S)	0.5001±0.1755	0.2031±0.0721	0.3516±0.21	0.4237±0.2257	0.1619±0.1067	0.3774±0.1305	0.321±0.1626
Chlorine (Cl)	0.2011±0.0650	0±0.0398	0.1006±0.1422	0.1687±0.2923	0±0.0707	0.1086±0.0333	0.0924±0.1747
Potassium (K)	2.7961±0.5479	2.8451±0.5498	2.8206±0.5488	2.8105±0.9518	2.6339±0.527	2.2158±0.4269	2.5534±0.6748
Calcium (Ca)	3.6212±0.5969	3.3487±1.554	3.485±1.1771	5.5414±2.9801	5.7244±4.0558	2.2566±0.3633	4.5075±2.9133
Titanium (Ti)	0.36±0.0478	0.5506±0.1261	0.4553±0.1348	0.4029±0.092	0.4549±0.0731	0.4649±0.0137	0.4409±0.0683
Vanadium (V)	0.0019±0.0310	0.0074±0.0217	0.0047±0.0267	0.0053±0.0676	0.0101±0.0538	0.0143±0.0182	0.0099±0.051
Chromium (Cr)	0.0009±0.0089	0.0008±0.0076	0.0008±0.0083	0.0006±0.0202	0.0028±0.0162	0.0093±0.0029	0.0042±0.0151
Manganese (Mn)	0.0752±0.0048	0.0766±0.0059	0.0759±0.0054	0.0969±0.0302	0.0861±0.0185	0.0751±0.0031	0.086±0.0205
Iron (Fe)	4.488±0.1665	5.9627±0.5818	5.2254±1.0428	5.2741±0.6007	5.1891±0.7571	6.0935±0.0686	5.5189±0.5594
Cobalt (Co)	0±0.0700	0.0044±0.093	0.0022±0.0823	0.001±0.0828	0±0.0816	0.0017±0.0948	0.0009±0.0866
Nickel (Ni)	0.0026±0.0020	0±0.0022	0.0013±0.0021	0.002±0.0055	0.0053±0.0043	0.0124±0.0009	0.0066±0.0053
Copper (Cu)	0.0252±0.0025	0.0084±0.003	0.0168±0.0119	0.0153±0.0072	0.0163±0.0113	0.0065±0.0006	0.0127±0.0078
Zinc (Zn)	0.1119±0.0047	0.0812±0.0658	0.0965±0.0467	0.039±0.0212	0.0358±0.0095	0.0208±0.0006	0.0319±0.0134
Gallium (Ga)	0.0011±0.0025	0.0018±0.0006	0.0014±0.0018	0±0.0047	0.001±0.0036	0±0.0007	0.0003±0.0035
Arsenic (As)	0.0021±0.0037	0.0011±0.0011	0.0016±0.0027	0.0021±0.0049	0.0009±0.0053	0.0012±0.0006	0.0014±0.0042
Selenium (Se)	0.0002±0.0013	0.0003±0.0005	0.0002±0.001	0.0004±0.0026	0.0003±0.002	0.0003±0.0004	0.0003±0.0019
Bromine (Br)	0.0025±0.0010	0.0008±0.0003	0.0016±0.0012	0.0015±0.0026	0.002±0.0015	0.0015±0.0003	0.0017±0.0017
Rubidium (Rb)	0.0107±0.0010	0.0171±0.0012	0.0139±0.0046	0.0156±0.0031	0.0125±0.0033	0.01±0.0003	0.0127±0.0028
Strontium (Sr)	0.0309±0.0015	0.0301±0.0017	0.0305±0.0016	0.0523±0.0109	0.0323±0.006	0.0254±0.0004	0.0367±0.014
Yttrium (Y)	0.0016±0.0012	0.0034±0.0007	0.0025±0.0013	0.0029±0.0029	0.0032±0.0019	0.003±0.0004	0.003±0.002
Zirconium (Zr)	0.0186±0.0016	0.0105±0.0033	0.0146±0.0057	0.0122±0.003	0.0111±0.0023	0.0144±0.0005	0.0126±0.0022
Molybdenum (Mo)	0.0007±0.0035	0±0.0011	0.0004±0.0026	0±0.0066	0.002±0.0051	0±0.001	0.0007±0.0048
Palladium (Pd)	0±0.0213	0.0001±0.007	0±0.0159	0±0.04	0.0014±0.0311	0±0.0063	0.0005±0.0295
Silver (Ag)	0±0.0249	0±0.0081	0±0.0185	0±0.0469	0±0.0367	0±0.0073	0±0.0346
Cadmium (Cd)	0±0.0263	0±0.0087	0±0.0196	0.0014±0.0494	0.0011±0.0387	0±0.0077	0.0008±0.0365
Indium (In)	0±0.0296	0.0004±0.0096	0.0002±0.022	0±0.056	0±0.0435	0±0.0087	0±0.0413
Tin (Sn)	0.0159±0.0374	0±0.012	0.008±0.0278	0.0074±0.0703	0.0078±0.0548	0.0015±0.0108	0.0056±0.0518
Antimony (Sb)	0.0215±0.0433	0.0018±0.0139	0.0116±0.0321	0.0076±0.082	0.0086±0.0637	0.001±0.0125	0.0057±0.0604
Barium (Ba)	0.1627±0.1055	0.0803±0.0318	0.1215±0.0779	0.0903±0.2757	0.0491±0.2126	0.0703±0.0283	0.0699±0.2017
Lanthanum (La)	0±0.2058	0.0221±0.0642	0.0111±0.1524	0.0948±0.3919	0.0675±0.3052	0±0.0576	0.0541±0.2887
Gold (Au)	0±0.0058	0.0006±0.0034	0.0003±0.0048	0.0019±0.0086	0.0003±0.0068	0±0.0014	0.0007±0.0064
Mercury (Hg)	0.0006±0.0030	0.0009±0.0009	0.0008±0.0022	0.0014±0.0057	0.0014±0.0044	0±0.0009	0.0009±0.0042
Thallium (Tl)	0±0.0030	0.0005±0.001	0.0003±0.0022	0.0003±0.0055	0.0005±0.0043	0±0.0009	0.0003±0.0041
Lead (Pb)	0.0161±0.0031	0.0057±0.0028	0.0109±0.0074	0.0058±0.0073	0.0203±0.0133	0.0043±0.0008	0.0101±0.0088
Uranium (U)	0.0009±0.0032	0.0013±0.0018	0.0011±0.0026	0.0017±0.0055	0.0028±0.0046	0±0.0015	0.0015±0.0042

	Agriculture					
Mnemonic[b] Source type County	FDALM Almonds Madera /Fresno /Kings/Kern	FDCOT Cotton Fresno /Kings /Kern	FDGRA Grape Kings /Kern	FDSAF Safflower Madera /Fresno	FDTOM Tomato Fresno	AGRI Composite
Chloride (Cl^-)	0.1355±0.3355	0.0363±0.0895	0.0311±0.0443	0.01±0.1891	0.0543±0.1296	0.0535±0.1871
Nitrate (NO_3^-)	0.0795±0.33	0±0.0891	0.0287±0.0465	0.0313±0.189	0±0.1289	0.0279±0.1851
Phosphate (PO_4^{2-})	0.0445±0.0771	0.0378±0.0844	0.0494±0.0699	0±0	0±0	0.0263±0.0599
Sulfate (SO_4^{2-})	1.0108±0.8997	0.0718±0.0894	0.0964±0.079	0.4295±0.2122	0.6627±0.3071	0.4542±0.4389
Ammonium (NH_4^+)	0.1983±0.3845	0.1259±0.1063	0.0815±0.0559	0.1808±0.225	0.1548±0.1523	0.1483±0.2173
Soluble sodium (Na^+)	0.1579±0.0685	0.0681±0.0361	0.0301±0.0111	0.1102±0.0383	0.1879±0.0995	0.1108±0.0643
Soluble potassium (K^+)	0.1208±0.0772	0.0794±0.0221	0.0812±0.0315	0.1004±0.0492	0.0759±0.0289	0.0915±0.0463
OC1	0.4906±0.609	0.018±0.1088	0.0267±0.0621	0.0957±0.251	0.1648±0.2043	0.1592±0.3135
OC2	0.5964±0.6908	0.3317±0.2078	0.17±0.0964	0.5013±0.3938	0.3439±0.2661	0.3887±0.3887
OC3	2.0633±2.1277	0.9371±0.5845	0.6277±0.2914	1.3392±1.1773	0.9536±0.7985	1.1842±1.1813
OC4	1.2002±0.8585	0.6334±0.234	0.5266±0.14	1.8938±1.6795	0.4182±0.3067	0.9344±0.8632
Pyrolyzed carbon (OP)	0.1888±0.6025	0.3233±0.2915	0.3098±0.3639	0.3254±0.3548	0.3231±0.3468	0.2941±0.4066
Organic carbon (OC)	4.5393±2.86	2.2435±0.8988	1.6607±0.5737	4.1554±1.971	2.2036±0.9841	2.9605±1.6835
EC1	0.1227±0.454	0.2499±0.1985	0.2857±0.3299	0.5474±0.2945	0.3524±0.2979	0.3116±0.3255
EC2	0.164±0.538	0.2348±0.1901	0.1485±0.1073	0.3054±0.3354	0.0964±0.2112	0.1898±0.3144
EC3	0±0.1495	0±0.0404	0±0.021	0±0.0857	0±0.0585	0±0.0839
Elemental carbon (EC)	0.0978±0.937	0.1614±0.3059	0.1244±0.1936	0.5274±0.5711	0.1257±0.3858	0.2073±0.5448
Total carbon (TC)	4.6371±3.0207	2.4049±0.9697	1.7851±0.6213	4.6827±1.9524	2.3293±1.0608	3.1678±1.7543
Carbonate carbon (C in CO_3^{2-})	1.8795±1.1522	0.4569±0.516	0.3404±0.0922	1.3355±0.6666	0.4893±0.605	0.9003±0.6947
Sodium (Na)	0.3301±0.2481	0.2163±0.177	0.3408±0.2488	0.2214±0.0882	0.0875±0.0326	0.2392±0.1809
Magnesium (Mg)	0.7532±0.0592	0.8253±0.2844	0.7249±0.0728	0.6527±0.0879	0.8603±0.2112	0.7633±0.1685
Aluminum (Al)	9.5792±2.8465	10.1887±3.0094	12.8924±3.7935	11.7164±3.5612	10.469±3.1005	10.9691±3.2816
Silicon (Si)	33.2764±10.4894	32.0343±10.0877	35.1638±11.0814	33.9564±10.9712	31.0187±9.7408	33.0899±10.4865
Phosphorus (P)	0.1573±0.1062	0.086±0.0438	0.1192±0.0883	0.0767±0.0465	0.0577±0.0301	0.0994±0.0694
Sulfur (S)	0.6607±0.554	0.0806±0.0356	0.0929±0.0345	0.1286±0.0509	0.1763±0.0693	0.2278±0.2517
Chlorine (Cl)	0.0021±0.0542	0.0011±0.0399	0±0.0519	0±0.0696	0±0.0332	0.0006±0.0513
Potassium (K)	3.0535±0.5984	2.3926±0.5877	3.4386±0.7674	2.6091±0.5577	2.0168±0.3922	2.7021±0.5928
Calcium (Ca)	3.2672±0.5694	2.0921±0.74	2.347±1.0742	2.5791±0.859	1.9597±0.6556	2.449±0.7992
Titanium (Ti)	0.3998±0.0477	0.419±0.0386	0.5323±0.0315	0.4355±0.0948	0.3973±0.0415	0.4368±0.0556
Vanadium (V)	0.0043±0.0333	0.0102±0.0255	0.0057±0.0264	0.0067±0.0738	0.0079±0.0267	0.007±0.0415
Chromium (Cr)	0.0013±0.0098	0.004±0.008	0.001±0.0086	0.0009±0.022	0.0059±0.0077	0.0026±0.0125
Manganese (Mn)	0.1036±0.0082	0.0777±0.0246	0.1079±0.0174	0.0831±0.0228	0.0743±0.0046	0.0893±0.0174
Iron (Fe)	4.3335±0.2331	5.2497±0.4788	5.6875±0.3575	5.2985±0.3721	5.21±0.2801	5.1559±0.4977
Cobalt (Co)	0.0009±0.0675	0.0002±0.0822	0±0.0886	0±0.0828	0±0.0812	0.0002±0.0808
Nickel (Ni)	0.0012±0.003	0.005±0.0061	0±0.0025	0.0006±0.0057	0.0078±0.0036	0.0029±0.0044
Copper (Cu)	0.0169±0.0082	0.0103±0.0058	0.0138±0.005	0.0271±0.0196	0.0203±0.0099	0.0177±0.011
Zinc (Zn)	0.1582±0.1838	0.0208±0.0057	0.0379±0.0124	0.0346±0.0113	0.0284±0.0074	0.056±0.0826
Gallium (Ga)	0.0004±0.0025	0.0004±0.0017	0.0001±0.0015	0±0.005	0.0009±0.0017	0.0004±0.0028
Arsenic (As)	0.0005±0.0029	0.0019±0.0016	0.0019±0.0013	0.0018±0.0054	0.0015±0.0013	0.0015±0.0029
Selenium (Se)	0.0004±0.0013	0.0002±0.0009	0.0001±0.0008	0.0002±0.0028	0.0003±0.0008	0.0002±0.0015
Bromine (Br)	0.0011±0.0013	0.0007±0.0008	0.0005±0.0009	0.0007±0.0025	0.0008±0.0009	0.0008±0.0014
Rubidium (Rb)	0.0147±0.0024	0.0118±0.0035	0.018±0.0032	0.0145±0.0025	0.0096±0.002	0.0137±0.0032
Strontium (Sr)	0.0338±0.0026	0.0275±0.0085	0.0311±0.0138	0.0333±0.0076	0.0214±0.0021	0.0294±0.0082
Yttrium (Y)	0.0023±0.0012	0.0026±0.0009	0.0026±0.0008	0.0021±0.0033	0.0026±0.0008	0.0024±0.0017
Zirconium (Zr)	0.0129±0.0045	0.0092±0.0023	0.0125±0.002	0.0085±0.003	0.0112±0.001	0.0109±0.0028
Molybdenum (Mo)	0.0004±0.0035	0.002±0.0022	0.0004±0.0021	0.0014±0.0071	0.0006±0.0022	0.001±0.0039
Palladium (Pd)	0.0004±0.021	0.0001±0.0144	0±0.0129	0±0.0426	0.0017±0.0137	0.0004±0.0237
Silver (Ag)	0.0004±0.0246	0.0001±0.0169	0.0032±0.0151	0.0045±0.0502	0.0002±0.0159	0.0017±0.0279
Cadmium (Cd)	0.0003±0.0261	0.0008±0.0179	0.0029±0.016	0.0076±0.0527	0.0022±0.0168	0.0027±0.0294
Indium (In)	0±0.0294	0.0003±0.0201	0±0.018	0±0.0595	0.0004±0.019	0.0001±0.0332
Tin (Sn)	0.0035±0.0368	0.0044±0.0252	0.0024±0.0225	0.0134±0.0739	0.0014±0.0237	0.005±0.0413
Antimony (Sb)	0.0102±0.0429	0.0026±0.0293	0.0098±0.026	0.0269±0.0876	0.0019±0.0276	0.0103±0.0486
Barium (Ba)	0.0875±0.1295	0.0609±0.0938	0.0919±0.0616	0.0954±0.292	0.0778±0.0898	0.0827±0.1566
Lanthanum (La)	0.0361±0.2038	0.0289±0.1391	0.038±0.1227	0.1216±0.4204	0.0358±0.1309	0.0521±0.2323
Gold (Au)	0.0001±0.0083	0.0002±0.0031	0.0004±0.003	0.001±0.009	0.0004±0.0029	0.0004±0.006
Mercury (Hg)	0.0014±0.0031	0.0008±0.002	0.0006±0.0018	0.0005±0.0062	0.0006±0.0019	0.0008±0.0034
Thallium (Tl)	0.001±0.0029	0.0005±0.0019	0.0004±0.0018	0.0004±0.006	0.0003±0.0018	0.0005±0.0033
Lead (Pb)	0.0063±0.0059	0.0031±0.0025	0.0062±0.0034	0.0024±0.0082	0.003±0.0025	0.0042±0.005
Uranium (U)	0.002±0.0034	0.0011±0.0024	0.0013±0.0029	0.001±0.0063	0.0008±0.0021	0.0012±0.0037

Table 3 (*continued*)

	Animal husbandry			Lake drainage	Construction/ earthmoving
Mnemonic[b]	FDCATDR	FDCATFL	CATTLE	SALTDEP	CONST
Source type	Dairy soil	Feedlot soil	Composite	Salt Deposits	Construction soil
County	Fresno/Kings	Fresno/Kern		Kings/Kern	Madera/Fresno
Chloride (Cl^-)	0.2762±0.1609	1.2595±0.7345	0.7679±0.6953	0.22±0.1181	0.021±0.1019
Nitrate (NO_3^-)	0.0277±0.0585	0±0.0547	0.0138±0.0566	0.1109±0.1568	0±0.1017
Phosphate (PO_4^{2})	1.5785±0.5953	3.5555±0.8813	2.567±1.398	0±0	0±0
Sulfate (SO_4^{2})	0.5026±0.0845	0.7284±0.2494	0.6155±0.1862	5.0975±0.5286	0.1163±0.1024
Ammonium (NH_4^+)	0.0326±0.0668	0.0577±0.0636	0.0451±0.0652	0.1143±0.1271	0.0755±0.1172
Soluble sodium (Na^+)	0.5026±0.467	0.5948±0.1599	0.5487±0.3491	2.2176±0.9064	0.0602±0.0387
Soluble potassium (K^+)	2.149±1.0547	2.6765±0.8705	2.4128±0.967	0.0607±0.0239	0.021±0.0212
OC1	0.0554±0.0788	0.1514±0.214	0.1034±0.1613	0.1216±0.1592	0±0.1149
OC2	2.3567±1.6349	2.7716±2.4584	2.5641±2.0877	0.3229±0.2274	0.3935±0.2142
OC3	10.4816±4.1057	8.4945±3.0922	9.488±3.6345	0.7148±0.6612	1.273±0.6476
OC4	5.2487±2.7679	4.0851±0.5848	4.6669±2.0004	0.9594±0.2934	0.8737±0.4827
Pyrolyzed carbon (OP)	0.9499±1.2311	2.3019±0.8774	1.6259±1.069	0.4594±0.6497	0.3615±0.49
Organic carbon (OC)	19.0922±7.3535	17.8043±7.2268	18.4483±7.2904	2.578±0.9663	2.9017±1.5444
EC1	1.2361±0.5653	2.1027±0.8162	1.6694±0.7021	0.4176±0.5906	0.5203±0.1912
EC2	0.4868±0.2606	0.4094±0.2178	0.4481±0.2401	0.1013±0.1786	0.1996±0.1925
EC3	0.0771±0.1091	0.0537±0.0759	0.0654±0.094	0±0.0491	0±0.0461
Elemental carbon (EC)	0.8502±0.5988	0.264±0.7532	0.5571±0.6804	0.0595±0.3635	0.3585±0.3735
Total carbon (TC)	19.9424±7.9523	18.0684±7.3271	19.0054±7.6461	2.6374±0.9388	3.2601±1.1709
Carbonate carbon (C in CO_3^{2})	0±0.1566	0.6106±0.1271	0.3053±0.4876	0.9148±0.3317	0.5312±0.5738
Sodium (Na)	0.1308±0.0599	0.22±0.0745	0.1754±0.0676	1.9573±1.5848	0.6153±0.0894
Magnesium (Mg)	0.9663±0.0907	1.8863±0.8027	1.4263±0.6506	0.7086±0.1391	0.7269±0.1698
Aluminum (Al)	9.4918±2.8323	4.6614±1.9858	7.0766±3.4156	9.7394±2.8788	12.3287±3.7469
Silicon (Si)	26.3307±8.3506	14.2277±4.5666	20.2792±8.5581	28.4962±8.946	38.2116±12.2911
Phosphorus (P)	0.9365±0.3954	4.014±2.3452	2.4752±2.1762	0±0.0674	0.0801±0.0458
Sulfur (S)	0.424±0.1533	0.5422±0.1904	0.4831±0.1728	3.5419±2.0069	0.1317±0.0529
Chlorine (Cl)	0.2017±0.0706	1.1842±0.5776	0.693±0.6947	0.2814±0.0893	0±0.0735
Potassium (K)	4.5868±0.9076	5.5383±1.0757	5.0625±0.9952	2.1944±0.4281	3.3042±0.6734
Calcium (Ca)	5.2901±0.883	5.3337±1.4414	5.3119±1.1952	4.2514±1.0576	5.1647±1.1624
Titanium (Ti)	0.3827±0.0609	0.22±0.0844	0.3013±0.1151	0.4028±0.0367	0.456±0.087
Vanadium (V)	0.0008±0.0488	0.003±0.0203	0.0019±0.0374	0.011±0.0256	0.0183±0.0504
Chromium (Cr)	0±0.015	0.0014±0.0059	0.0007±0.0114	0.0008±0.0079	0.0039±0.0136
Manganese (Mn)	0.0757±0.0061	0.0759±0.0074	0.0758±0.0067	0.0743±0.0364	0.1108±0.0141
Iron (Fe)	4.8499±0.2273	2.5828±1.0029	3.7163±1.603	4.6795±0.7735	4.595±0.5694
Cobalt (Co)	0±0.0757	0±0.0418	0±0.0612	0.0036±0.0734	0.0052±0.0721
Nickel (Ni)	0.0008±0.0038	0.0008±0.0018	0.0008±0.003	0.0009±0.0027	0.0041±0.0044
Copper (Cu)	0.0126±0.003	0.0132±0.0058	0.0129±0.0046	0.011±0.0087	0.013±0.006
Zinc (Zn)	0.0453±0.0209	0.0343±0.0086	0.0398±0.016	0.0158±0.0035	0.0283±0.0088
Gallium (Ga)	0±0.0032	0.001±0.0016	0.0005±0.0026	0.0001±0.002	0±0.0043
Arsenic (As)	0.0014±0.0035	0.0016±0.0017	0.0015±0.0028	0.0046±0.0025	0.0008±0.0048
Selenium (Se)	0.0002±0.0017	0.0001±0.0009	0.0002±0.0014	0±0.0011	0.001±0.0024
Bromine (Br)	0.0011±0.0017	0.0045±0.0016	0.0028±0.0024	0.0019±0.0008	0.0006±0.0023
Rubidium (Rb)	0.0149±0.0013	0.0137±0.0035	0.0143±0.0026	0.0126±0.0008	0.0162±0.0019
Strontium (Sr)	0.0337±0.002	0.0255±0.009	0.0296±0.0065	0.0462±0.0045	0.0537±0.0041
Yttrium (Y)	0.0018±0.0022	0.0013±0.0012	0.0015±0.0017	0.0022±0.001	0.0027±0.0021
Zirconium (Zr)	0.0098±0.0048	0.0043±0.001	0.0071±0.0039	0.0087±0.0047	0.0122±0.0027
Molybdenum (Mo)	0±0.0045	0.001±0.0023	0.0005±0.0036	0.0054±0.0037	0.0022±0.0059
Palladium (Pd)	0±0.0274	0±0.014	0±0.0217	0±0.0168	0.0017±0.0372
Silver (Ag)	0.0034±0.0321	0±0.0164	0.0017±0.0255	0±0.0196	0±0.0435
Cadmium (Cd)	0±0.0341	0±0.0174	0±0.0271	0.0012±0.0209	0±0.0458
Indium (In)	0±0.0386	0.0004±0.0195	0.0002±0.0306	0±0.0234	0±0.0515
Tin (Sn)	0.0127±0.0486	0.0017±0.0245	0.0072±0.0385	0.0055±0.0294	0.0024±0.0647
Antimony (Sb)	0.0074±0.0566	0.0019±0.0286	0.0046±0.0448	0.011±0.0342	0.0132±0.0754
Barium (Ba)	0.0669±0.1879	0.0469±0.0929	0.0569±0.1482	0.0498±0.1148	0.0862±0.2517
Lanthanum (La)	0.1359±0.269	0.0263±0.1356	0.0811±0.213	0.0117±0.1623	0.0024±0.3596
Gold (Au)	0.0005±0.006	0.0004±0.0031	0.0004±0.0048	0±0.0035	0.0005±0.0078
Mercury (Hg)	0.0001±0.004	0.0004±0.0019	0.0003±0.0031	0.0006±0.0024	0.0017±0.0052
Thallium (Tl)	0.0004±0.0038	0.0001±0.0019	0.0003±0.003	0±0.0023	0.0005±0.005
Lead (Pb)	0.0013±0.0052	0.0035±0.002	0.0024±0.004	0.001±0.0032	0.0084±0.0055
Uranium (U)	0.0011±0.0043	0.0009±0.0026	0.001±0.0035	0.0029±0.0024	0.0018±0.0054

[a] Values represent averages and uncertainties (the higher of the root mean squared error or standard deviation of the average).
[b] See Fig. 1 for the hierarchy of profile composite scheme.

Fig. 2. Maximum-to-minimum (max/min) abundance ratios were compared across profiles for the 59 reported species. Substantial differences with max/min ratios exceeding 10 occur among the six Level V composite profiles, with the highest abundances of EC2, EC, and Pb in the paved road dust profile; highest SO_4^{2} , S, Na^+, and Mo abundances in the salt deposit profile; and highest Cl , K^+, OC3, and La in the animal husbandry profile. Total carbon abundances range from $2.6 \pm 0.94\%$ in the salt deposit profile to $19 \pm 7.6\%$ in the animal husbandry profile. Max/min ratios of carbon fractions among the six source types range from 5 to 17. OC1 ($0.27 \pm 0.30\%$), EC2 ($1.0 \pm 0.9\%$), and EC ($1.0 \pm 0.9\%$) abundances in paved road dust are 3–10

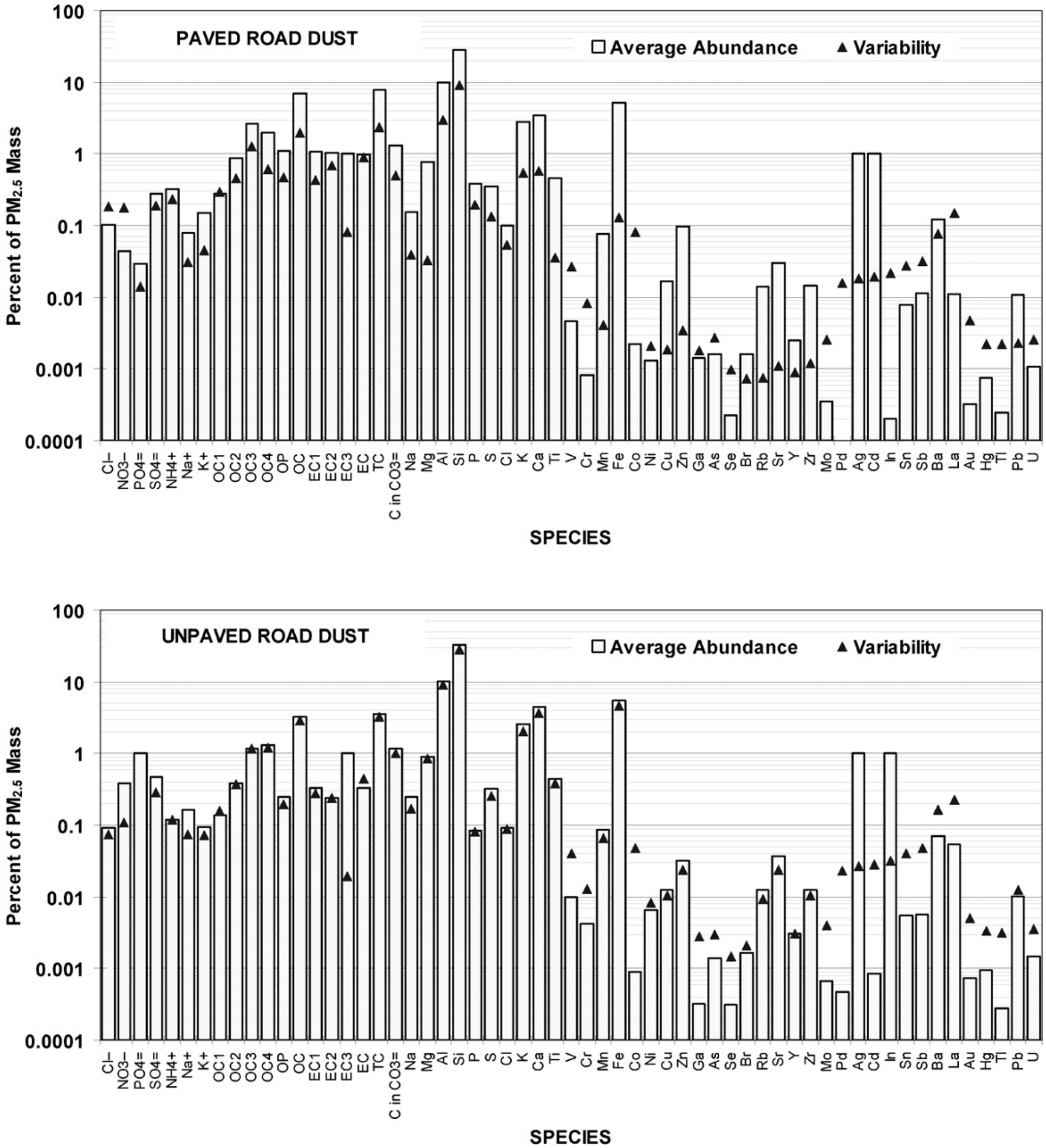
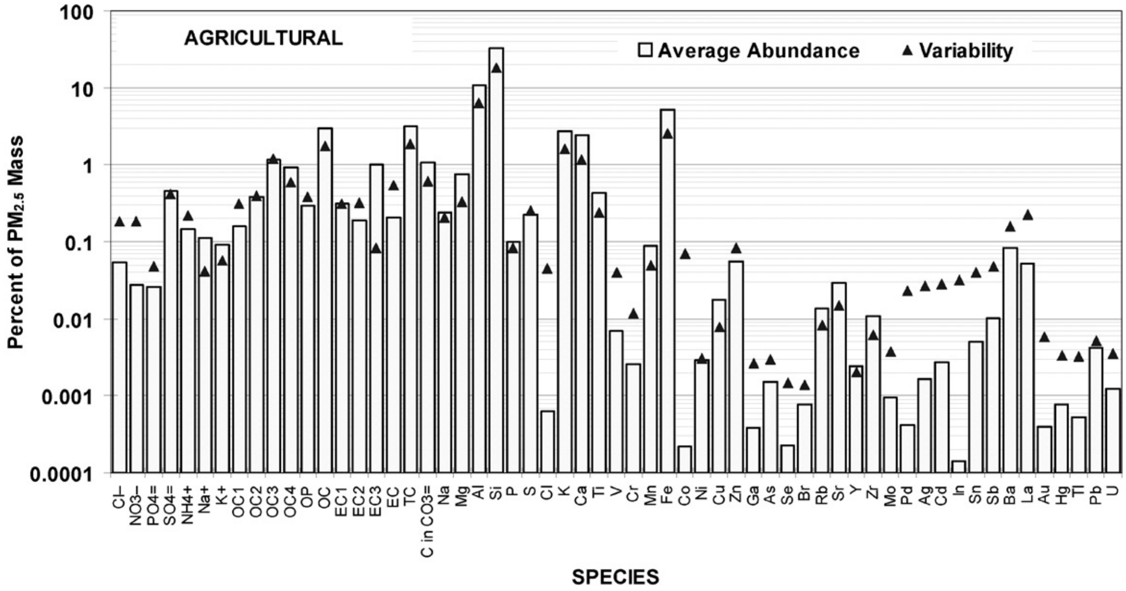


Fig. 2. Geological source profiles of paved road dust (PVRD), unpaved road dust (UNPVRD), agricultural soil (AGRI), animal husbandry (CATTLE), disturbed land (SALTDEP), and construction site soil (CONST) from California's SJV. The height of each bar indicates the percent of the corresponding chemical species in emitted PM_{10}. The position of the triangle shows the variability in percent composition which includes measurement errors and source variabilities.



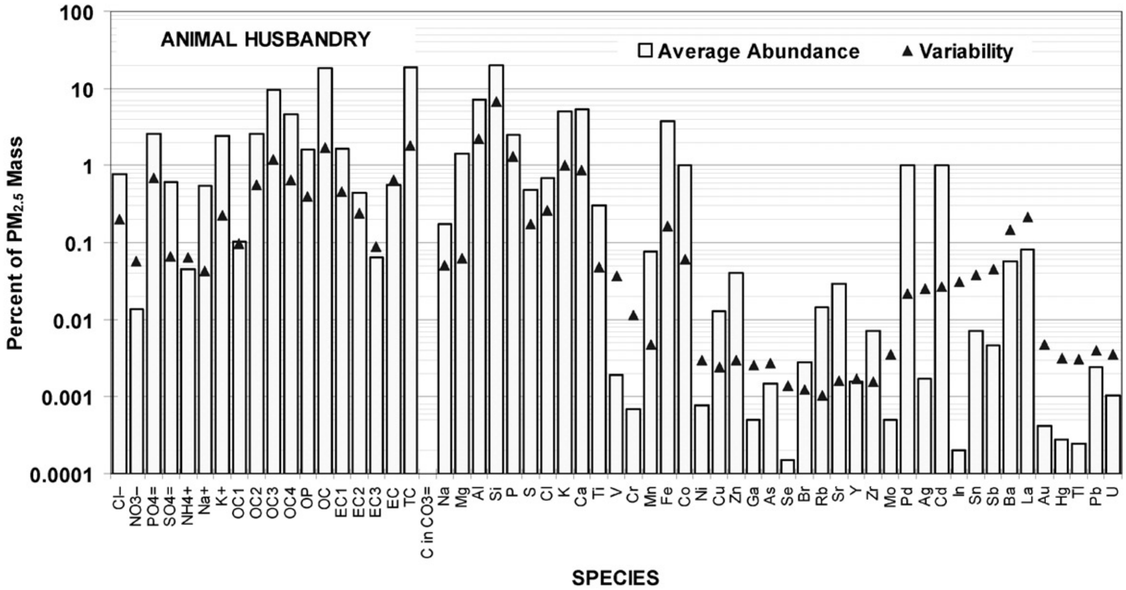
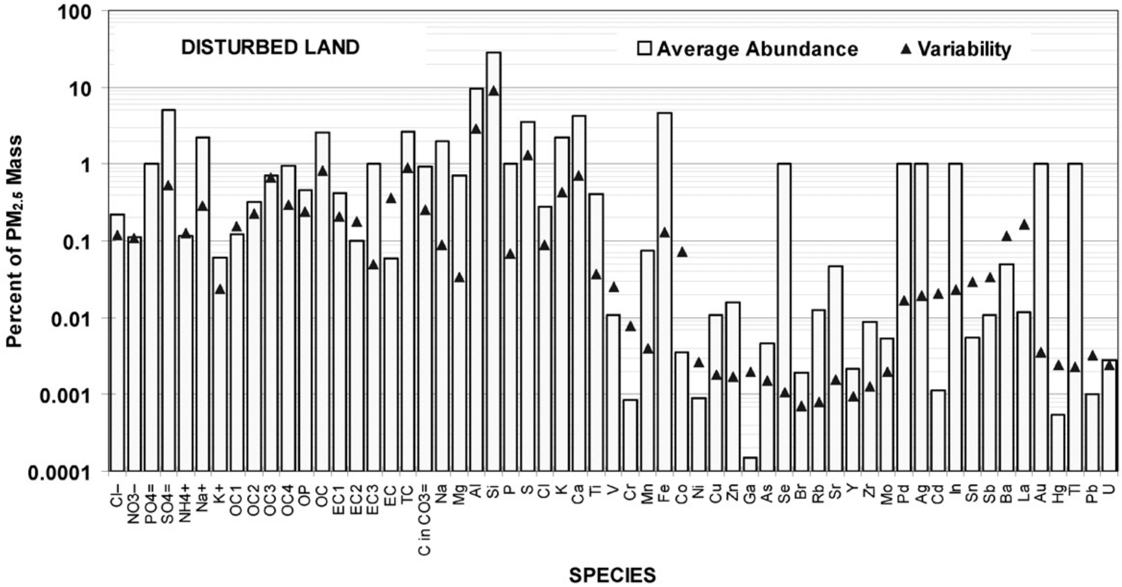


Fig. 2 (*continued*).

times the abundances in other profiles; the other carbon fractions are 5–17 times more abundant in the animal husbandry profile. Carbonate carbon ($1.3 \pm 0.6\%$) is most abundant in the paved road dust profiles.

OC/EC ratios range from 7 to 10 in the paved road dust, unpaved road dust, and construction dust; this ratio is 14 in the agricultural profile, 33 in the animal husbandry profile, and 43 in the salt deposit profile. Higher OC/EC ratios in the animal husbandry and salt deposit profiles result from low EC abundances ($<0.5\%$). Most (65–76%) of the OC is in the high-temperature OC3 and OC4 fractions, while over 50% of EC is in the EC1 fraction except for elevated levels of EC2 in paved road dust. These higher OC1 and EC2 abundances in paved road dust are consistent with diesel profiles reported by Watson et al. (1994) and might result from deposition of vehicle exhaust onto the roadway. The carbonate carbon exceeds 0.9% in the paved and unpaved road dust and agricultural profiles. Though present at trace levels (0.001–0.1%), Zn, Ga, Zr, Sn, Ba, and Pb are 2–8 times more abundant in the paved road dust profile than in other profiles.



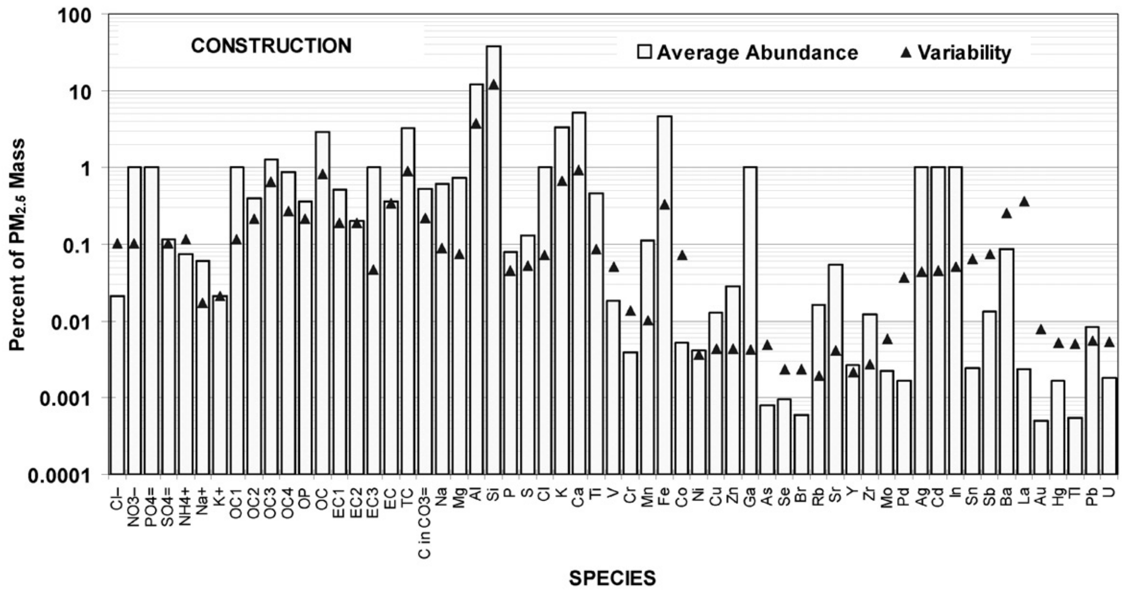


Fig. 2 (*continued*).

The unpaved road dust profile is similar to other geological profiles, but with higher NO_3 ($0.39 \pm 0.87\%$) and 6–8 times higher Cr and Ni. OC and EC in unpaved road dust are 40–50% less than in paved road dust. Water-soluble ion abundances from canal drainage are 10–40 times higher for Na^+, Na, S, and SO_4^2 ; Cl and Cl are also 2–10 times more abundant than in other profiles, with the exception of animal husbandry. The Presence of Na_2SO_4 and NaCl salts is apparent.

Toxic species such as As, Mo, Cd, Sb, and U are detectable (0.0012–0.01%) in salt deposits, and are 2–15 times higher than in other geological profiles. Most abundant geological species (Al, Si), transition metals (Ti, V, Mn, Co, Hg, Pd), alkali and rare earth metals (Rb, Sr), as well as Tl and Se are highest in the construction profile. Al is 12–74% and Si is 15–88% more abundant in the construction profile than in the other profiles. Ca is also enriched ($5.2 \pm 1.2\%$) in the construction profile, but is similar to the abundance in the animal husbandry profile ($5.3 \pm 1.2\%$). Carbonate carbon accounts for only $0.53 \pm 0.57\%$ of PM_{10} mass in construction, 30–50% lower than its abundances in the

Table 4
Comparison between current and 1987 geological source profiles (in percent of PM_{10} mass) for the San Joaquin Valley, California.

	Paved road dust			
Mnemonic	FDPVR1	SOIL03 (1987)	SOIL08 (1987)	SOIL12 (1987)
Source type	Urban Paved Road	Paved Road	Paved Road	Paved Road
Location		Fresno	Visalia	Bakersfield/Oildale/Taft
Chloride (Cl^-)	0.0954 ± 0.2220	n/a ± n/a	n/a ± n/a	n/a ± n/a
Nitrate (NO_3^-)	0.0000 ± 0.2204	0.0000 ± 0.4700	0.1000 ± 0.4200	0.0900 ± 0.3200
Phosphate (PO_4^{2-})	0.0000 ± 0.0000	n/a ± n/a	n/a ± n/a	n/a ± n/a
Sulfate (SO_4^{2-})	0.3074 ± 0.2290	0.5500 ± 1.1700	0.2300 ± 0.1500	0.4100 ± 0.4300
Ammonium (NH_4^+)	0.4272 ± 0.2818	0.0000 ± 0.0100	0.0500 ± 0.0100	0.0000 ± 0.0100
Soluble Sodium (Na^+)	0.0869 ± 0.0379	0.1800 ± 0.0500	0.1200 ± 0.0500	0.1300 ± 0.0800
Soluble Potassium (K^+)	0.1480 ± 0.0561	0.3400 ± 0.1200	0.2100 ± 0.0400	0.1900 ± 0.0900
Organic Carbon (OC)	9.5322 ± 2.5953	19.4700 ± 4.6700	11.5200 ± 1.8300	13.5400 ± 1.3600
Elemental Carbon (EC)	1.6678 ± 1.1784	2.6900 ± 1.4400	1.7400 ± 1.0900	1.0900 ± 0.7600
Total Carbon (TC)	11.2000 ± 3.0696	22.1600 ± 4.8870	13.2600 ± 2.1300	14.6300 ± 1.5579
Carbonate Carbon (C in CO_3^{2-})	1.8728 ± 0.6288	0.2256 ± 0.3070	0.2161 ± 0.2737	0.2696 ± 0.2090
Sodium (Na)	0.1519 ± 0.0502	n/a ± n/a	n/a ± n/a	n/a ± n/a
Magnesium (Mg)	0.7536 ± 0.0427	n/a ± n/a	n/a ± n/a	n/a ± n/a
Aluminum (Al)	7.9862 ± 2.3696	9.4000 ± 1.1100	9.2100 ± 1.0400	7.9000 ± 0.8900
Silicon (Si)	23.4286 ± 7.3732	23.2400 ± 2.6200	22.5200 ± 2.5300	21.1300 ± 2.3700
Phosporus (P)	0.6382 ± 0.2699	0.3000 ± 0.0500	0.2800 ± 0.0300	0.3500 ± 0.0500
Sulfur (S)	0.5001 ± 0.1755	0.5200 ± 0.1700	0.4600 ± 0.0800	0.4400 ± 0.0700
Chlorine (Cl)	0.2011 ± 0.0650	0.1600 ± 0.0300	0.1500 ± 0.0200	0.3400 ± 0.0500
Potassium (K)	2.7961 ± 0.5479	1.9500 ± 0.2800	2.3200 ± 0.2600	2.0400 ± 0.2300
Calcium (Ca)	3.6212 ± 0.5969	2.9800 ± 0.4300	3.7000 ± 0.5300	4.2100 ± 0.4700
Titanium (Ti)	0.3600 ± 0.0478	0.5000 ± 0.0700	0.7400 ± 0.0800	0.4800 ± 0.0500
Vanadium (V)	0.0019 ± 0.0310	0.0300 ± 0.0100	0.0400 ± 0.0100	0.0300 ± 0.0100
Chromium (Cr)	0.0009 ± 0.0089	0.0300 ± 0.0000	0.0300 ± 0.0000	0.0300 ± 0.0000
Manganese (Mn)	0.0752 ± 0.0048	0.1100 ± 0.0200	0.1100 ± 0.0100	0.0900 ± 0.0100
Iron (Fe)	4.4880 ± 0.1665	5.4100 ± 0.8800	6.3300 ± 0.7100	5.4900 ± 0.6100
Cobalt (Co)	0.0000 ± 0.0700	0.0100 ± 0.0800	0.0200 ± 0.0900	0.0200 ± 0.0800
Nickel (Ni)	0.0026 ± 0.0020	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000
Copper (Cu)	0.0252 ± 0.0025	0.0200 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000
Zinc (Zn)	0.1119 ± 0.0047	0.1700 ± 0.0300	0.1500 ± 0.0200	0.1800 ± 0.0100
Gallium (Ga)	0.0011 ± 0.0025	0.0000 ± 0.0100	0.0000 ± 0.0000	0.0000 ± 0.0000
Arsenic (As)	0.0021 ± 0.0037	0.0000 ± 0.0400	0.0000 ± 0.0200	0.0000 ± 0.0300
Selenium (Se)	0.0002 ± 0.0013	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Bromine (Br)	0.0025 ± 0.0010	0.0100 ± 0.0000	0.0000 ± 0.0000	0.0100 ± 0.0000
Rubidium (Rb)	0.0107 ± 0.0010	0.0100 ± 0.0000	0.0200 ± 0.0000	0.0100 ± 0.0000
Strontium (Sr)	0.0309 ± 0.0015	0.0800 ± 0.0100	0.0300 ± 0.0000	0.0500 ± 0.0000
Yttrium (Y)	0.0016 ± 0.0012	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Zirconium (Zr)	0.0186 ± 0.0016	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000
Molybdenum (Mo)	0.0007 ± 0.0035	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0000
Palladium (Pd)	0.0000 ± 0.0213	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100
Silver (Ag)	0.0000 ± 0.0249	0.0000 ± 0.0200	0.0000 ± 0.0100	0.0000 ± 0.0100
Cadmium (Cd)	0.0000 ± 0.0263	0.0000 ± 0.0200	0.0000 ± 0.0100	0.0000 ± 0.0100
Indium (In)	0.0000 ± 0.0296	0.0000 ± 0.0200	0.0000 ± 0.0200	0.0000 ± 0.0100
Tin (Sn)	0.0159 ± 0.0374	0.0000 ± 0.0300	0.0100 ± 0.0200	0.0000 ± 0.0200
Antimony (Sb)	0.0215 ± 0.0433	0.0100 ± 0.0300	0.0000 ± 0.0300	0.0000 ± 0.0200
Barium (Ba)	0.1627 ± 0.1055	0.0600 ± 0.1000	0.0900 ± 0.0800	0.1000 ± 0.0500
Lanthanum (La)	0.0000 ± 0.2058	0.0100 ± 0.1200	0.0100 ± 0.1100	0.0100 ± 0.0800
Gold (Au)	0.0000 ± 0.0058	n/a ± n/a	n/a ± n/a	n/a ± n/a
Mercury (Hg)	0.0006 ± 0.0030	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100
Thallium (Tl)	0.0000 ± 0.0030	n/a ± n/a	n/a ± n/a	n/a ± n/a
Lead (Pb)	0.0161 ± 0.0031	0.2600 ± 0.0300	0.1400 ± 0.0100	0.1600 ± 0.0200
Uranium (U)	0.0009 ± 0.0032	n/a ± n/a	n/a ± n/a	n/a ± n/a

	Unpaved road dust		
Mnemonic	UNPVRD	SOIL07 (1987)	SOIL11 (1987)
Source type	Unpaved Road Dust Composite	Urban Unpaved Road	Unpaved Road
Location		Visalia	Bakersfield/Oildale/Taft
Chloride (Cl^-)	0.0911 ± 0.1188	n/a ± n/a	n/a ± n/a
Nitrate (NO_3^-)	0.3881 ± 0.8696	0.1900 ± 0.2600	0.0500 ± 0.2900
Phosphate (PO_4^{2-})	0.0000 ± 0.0000	n/a ± n/a	n/a ± n/a
Sulfate (SO_4^{2-})	0.4770 ± 0.3163	0.0700 ± 0.0900	0.2200 ± 0.1000
Ammonium (NH_4^+)	0.1202 ± 0.1141	0.0000 ± 0.0000	0.0000 ± 0.0000
Soluble Sodium (Na^+)	0.1662 ± 0.1974	1.1100 ± 1.8100	0.2300 ± 0.0400
Soluble Potassium (K^+)	0.0951 ± 0.0636	0.1400 ± 0.0300	0.1000 ± 0.0300
Organic Carbon (OC)	3.2399 ± 1.4406	3.5800 ± 0.9600	0.8700 ± 0.7900
Elemental Carbon (EC)	0.3276 ± 0.3346	0.2000 ± 0.1900	0.0100 ± 0.1300
Total Carbon (TC)	3.5674 ± 1.4549	3.7800 ± 0.9786	0.8800 ± 0.8006
Carbonate Carbon (C in CO_3^{2-})	1.1618 ± 0.3069	0.1699 ± 0.1710	0.7258 ± 0.1943
Sodium (Na)	0.2499 ± 0.2548	n/a ± n/a	n/a ± n/a
Magnesium (Mg)	0.9099 ± 0.2823	n/a ± n/a	n/a ± n/a
Aluminum (Al)	10.2416 ± 3.9377	9.8300 ± 1.1100	9.9300 ± 1.1200
Silicon (Si)	32.9153 ± 11.7657	22.5300 ± 2.5400	24.9400 ± 2.8000
Phosporus (P)	0.0850 ± 0.0524	0.1700 ± 0.0200	0.2000 ± 0.0200
Sulfur (S)	0.3210 ± 0.1626	0.0800 ± 0.0300	0.1500 ± 0.0200
Chlorine (Cl)	0.0924 ± 0.1747	0.1000 ± 0.0100	0.1300 ± 0.0200
Potassium (K)	2.5534 ± 0.6748	2.4600 ± 0.2800	2.1000 ± 0.2400
Calcium (Ca)	4.5075 ± 2.9133	3.2200 ± 0.3600	7.4000 ± 0.8300
Titanium (Ti)	0.4409 ± 0.0683	0.7600 ± 0.0900	0.5800 ± 0.0600
Vanadium (V)	0.0099 ± 0.0510	0.0400 ± 0.0100	0.0400 ± 0.0100
Chromium (Cr)	0.0042 ± 0.0151	0.0300 ± 0.0000	0.0300 ± 0.0000
Manganese (Mn)	0.0860 ± 0.0205	0.1300 ± 0.0100	0.1100 ± 0.0100
Iron (Fe)	5.5189 ± 0.5594	8.0600 ± 0.9100	6.0500 ± 0.6800
Cobalt (Co)	0.0009 ± 0.0866	0.0100 ± 0.1100	0.0200 ± 0.0800
Nickel (Ni)	0.0066 ± 0.0053	0.0100 ± 0.0000	0.0100 ± 0.0000
Copper (Cu)	0.0127 ± 0.0078	0.0100 ± 0.0000	0.0100 ± 0.0000
Zinc (Zn)	0.0319 ± 0.0134	0.1800 ± 0.0100	0.0200 ± 0.0000
Gallium (Ga)	0.0003 ± 0.0035	0.0000 ± 0.0000	0.0000 ± 0.0000
Arsenic (As)	0.0014 ± 0.0042	0.0000 ± 0.0500	0.0000 ± 0.0000
Selenium (Se)	0.0003 ± 0.0019	0.0000 ± 0.0000	0.0000 ± 0.0000
Bromine (Br)	0.0017 ± 0.0017	0.0000 ± 0.0000	0.0000 ± 0.0000
Rubidium (Rb)	0.0127 ± 0.0028	0.0200 ± 0.0000	0.0200 ± 0.0000
Strontium (Sr)	0.0367 ± 0.0140	0.0300 ± 0.0000	0.0400 ± 0.0000
Yttrium (Y)	0.0030 ± 0.0020	0.0000 ± 0.0000	0.0000 ± 0.0000
Zirconium (Zr)	0.0126 ± 0.0022	0.0100 ± 0.0000	0.0100 ± 0.0000
Molybdenum (Mo)	0.0007 ± 0.0048	0.0000 ± 0.0000	0.0000 ± 0.0000
Palladium (Pd)	0.0005 ± 0.0295	0.0000 ± 0.0100	0.0000 ± 0.0100
Silver (Ag)	0.0000 ± 0.0346	0.0000 ± 0.0100	0.0000 ± 0.0100
Cadmium (Cd)	0.0008 ± 0.0365	0.0100 ± 0.0100	0.0000 ± 0.0100
Indium (In)	0.0000 ± 0.0413	0.0000 ± 0.0100	0.0000 ± 0.0100
Tin (Sn)	0.0056 ± 0.0518	0.0000 ± 0.0200	0.0000 ± 0.0200
Antimony (Sb)	0.0057 ± 0.0604	0.0000 ± 0.0200	0.0000 ± 0.0200
Barium (Ba)	0.0699 ± 0.2017	0.1400 ± 0.0200	0.1000 ± 0.0200
Lanthanum (La)	0.0541 ± 0.2887	0.0100 ± 0.0700	0.0000 ± 0.0700
Gold (Au)	0.0007 ± 0.0064	n/a ± n/a	n/a ± n/a
Mercury (Hg)	0.0009 ± 0.0042	0.0000 ± 0.0000	0.0000 ± 0.0000
Thallium (Tl)	0.0003 ± 0.0041	n/a ± n/a	n/a ± n/a
Lead (Pb)	0.0101 ± 0.0088	0.3200 ± 0.0200	0.0100 ± 0.0000
Uranium (U)	0.0015 ± 0.0042	n/a ± n/a	n/a ± n/a

Table 4 (*continued*)

	Unpaved road dust (continued)		
Mnemonic	SOIL13 (1987)	SOIL16 (1987)	SOIL17 (1987)
Source type	Unpaved Parking Lot and Alley	Residential Unpaved Road	Unpaved Road
Location	Bakersfield/Oildale/Taft	Bakersfield/Oildale/Taft	Taft
Chloride (Cl^-)	n/a ± n/a	n/a ± n/a	n/a ± n/a
Nitrate (NO_3^-)	0.1500 ± 0.2300	0.1700 ± 0.2400	0.0500 ± 0.1300
Phosphate (PO_4^{2-})	n/a ± n/a	n/a ± n/a	n/a ± n/a
Sulfate (SO_4^{2-})	0.3600 ± 0.3900	0.1200 ± 0.0900	0.2300 ± 0.3400
Ammonium (NH_4^+)	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0700 ± 0.0100
Soluble Sodium (Na^+)	0.0900 ± 0.0300	0.0700 ± 0.0300	0.0600 ± 0.0400
Soluble Potassium (K^+)	0.1800 ± 0.0400	0.2100 ± 0.0700	0.1200 ± 0.0500
Organic Carbon (OC)	7.5600 ± 1.0700	3.5800 ± 0.6000	3.6900 ± 0.4700
Elemental Carbon (EC)	0.1200 ± 0.1100	0.0000 ± 0.1100	0.0700 ± 0.0600
Total Carbon (TC)	7.6800 ± 1.0756	3.5800 ± 0.6100	3.7600 ± 0.4738
Carbonate Carbon (C in CO_3^{2-})	0.0555 ± 0.1527	0.0819 ± 0.1580	0.1080 ± 0.0847
Sodium (Na)	n/a ± n/a	n/a ± n/a	n/a ± n/a
Magnesium (Mg)	n/a ± n/a	n/a ± n/a	n/a ± n/a
Aluminum (Al)	10.8100 ± 1.9400	10.7300 ± 1.2000	7.6100 ± 1.2100
Silicon (Si)	25.1500 ± 5.0600	23.8500 ± 2.6700	23.4700 ± 3.3000
Phosporus (P)	0.2800 ± 0.0300	0.1800 ± 0.0200	0.1300 ± 0.0200
Sulfur (S)	0.2300 ± 0.0300	0.1200 ± 0.0100	0.1300 ± 0.0100
Chlorine (Cl)	0.2000 ± 0.0500	0.1100 ± 0.0100	0.0800 ± 0.0100
Potassium (K)	2.9000 ± 0.7300	2.7300 ± 0.3100	2.2800 ± 0.2600
Calcium (Ca)	3.3100 ± 0.7000	2.1100 ± 0.2400	2.0900 ± 0.2400
Titanium (Ti)	0.7900 ± 0.2000	0.6700 ± 0.0800	0.4700 ± 0.0500
Vanadium (V)	0.0500 ± 0.0100	0.0400 ± 0.0100	0.0300 ± 0.0100
Chromium (Cr)	0.0300 ± 0.0100	0.0300 ± 0.0000	0.0200 ± 0.0000
Manganese (Mn)	0.2300 ± 0.0500	0.1300 ± 0.0100	0.0800 ± 0.0100
Iron (Fe)	9.1600 ± 2.2700	7.6200 ± 0.8500	4.7000 ± 0.5300
Cobalt (Co)	0.0300 ± 0.1300	0.0200 ± 0.1100	0.0100 ± 0.0700
Nickel (Ni)	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000
Copper (Cu)	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000
Zinc (Zn)	0.1100 ± 0.0200	0.0200 ± 0.0000	0.0400 ± 0.0000
Gallium (Ga)	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Arsenic (As)	0.0000 ± 0.0300	0.0000 ± 0.0000	0.0000 ± 0.0100
Selenium (Se)	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Bromine (Br)	0.0100 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Rubidium (Rb)	0.0300 ± 0.0100	0.0200 ± 0.0000	0.0100 ± 0.0000
Strontium (Sr)	0.0500 ± 0.0200	0.0300 ± 0.0000	0.0300 ± 0.0000
Yttrium (Y)	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Zirconium (Zr)	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000
Molybdenum (Mo)	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Palladium (Pd)	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0000
Silver (Ag)	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0000
Cadmium (Cd)	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100
Indium (In)	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100
Tin (Sn)	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100
Antimony (Sb)	0.0000 ± 0.0200	0.0000 ± 0.0200	0.0000 ± 0.0100
Barium (Ba)	0.1100 ± 0.0400	0.0700 ± 0.0400	0.1100 ± 0.0100
Lanthanum (La)	0.0100 ± 0.0600	0.0000 ± 0.0600	0.0000 ± 0.0300
Gold (Au)	n/a ± n/a	n/a ± n/a	n/a ± n/a
Mercury (Hg)	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Thallium (Tl)	n/a ± n/a	n/a ± n/a	n/a ± n/a
Lead (Pb)	0.1600 ± 0.0300	0.0100 ± 0.0000	0.0400 ± 0.0000
Uranium (U)	n/a ± n/a	n/a ± n/a	n/a ± n/a

	Agricultural soil			
Mnemonic	AGRI	SOIL04 (1987)	SOIL05 (1987)	SOIL09 (1987)
Source type	Agricultural Soil Composite	Cotton Field/ Walnut Grove	Grape Vineyard	Cotton Field
Location		Visalia	Visalia	Bakersfield/Oildale/Taft
Chloride (Cl^-)	0.0535 ± 0.1871	n/a ± n/a	n/a ± n/a	n/a ± n/a
Nitrate (NO_3^-)	0.0279 ± 0.1851	0.0000 ± 0.2100	0.0300 ± 0.2300	0.0700 ± 0.2700
Phosphate (PO_4^{2-})	0.0263 ± 0.0599	n/a ± n/a	n/a ± n/a	n/a ± n/a
Sulfate (SO_4^{2-})	0.4542 ± 0.4389	0.0000 ± 0.0800	0.0300 ± 0.0800	0.4100 ± 0.5400
Ammonium (NH_4^+)	0.1483 ± 0.2173	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Soluble Sodium (Na^+)	0.1108 ± 0.0643	0.0900 ± 0.0300	0.0800 ± 0.0300	0.6600 ± 0.1900
Soluble Potassium (K^+)	0.0915 ± 0.0463	0.1900 ± 0.0500	0.1700 ± 0.0400	0.1800 ± 0.1100
Organic Carbon (OC)	2.9605 ± 1.6835	2.4900 ± 0.6100	2.2900 ± 0.4700	1.0500 ± 0.6800
Elemental Carbon (EC)	0.2073 ± 0.5448	0.0000 ± 0.1000	0.0000 ± 0.1100	0.0000 ± 0.1300
Total Carbon (TC)	3.1678 ± 1.7543	2.4900 ± 0.6181	2.2900 ± 0.4827	1.0500 ± 0.6923
Carbonate Carbon (C in CO_3^{2-})	0.9003 ± 0.6947	0.3259 ± 0.1404	0.0658 ± 0.1524	0.1971 ± 0.1778
Sodium (Na)	0.2392 ± 0.1809	n/a ± n/a	n/a ± n/a	n/a ± n/a
Magnesium (Mg)	0.7633 ± 0.1685	n/a ± n/a	n/a ± n/a	n/a ± n/a
Aluminum (Al)	10.9691 ± 3.2816	9.9600 ± 1.5800	12.4700 ± 1.6100	10.5700 ± 1.1900
Silicon (Si)	33.0899 ± 10.4865	24.6400 ± 3.8700	25.9500 ± 3.1100	26.8400 ± 3.0200
Phosporus (P)	0.0994 ± 0.0694	0.2200 ± 0.0300	0.1600 ± 0.0300	0.1700 ± 0.0200
Sulfur (S)	0.2278 ± 0.2517	0.0700 ± 0.0100	0.1100 ± 0.0200	0.4700 ± 0.0700
Chlorine (Cl)	0.0006 ± 0.0513	0.1100 ± 0.0100	0.1200 ± 0.0500	0.4100 ± 0.0500
Potassium (K)	2.7021 ± 0.5928	3.1500 ± 0.3600	2.6700 ± 0.3000	2.7200 ± 0.3100
Calcium (Ca)	2.4490 ± 0.7992	3.4900 ± 0.4000	1.4700 ± 0.1700	2.2700 ± 0.2600
Titanium (Ti)	0.4368 ± 0.0556	0.8000 ± 0.0900	0.7300 ± 0.0800	0.6600 ± 0.0700
Vanadium (V)	0.0070 ± 0.0415	0.0400 ± 0.0100	0.0400 ± 0.0100	0.0400 ± 0.0100
Chromium (Cr)	0.0026 ± 0.0125	0.0300 ± 0.0000	0.0300 ± 0.0000	0.0300 ± 0.0000
Manganese (Mn)	0.0893 ± 0.0174	0.1300 ± 0.0100	0.1600 ± 0.0200	0.1300 ± 0.0100
Iron (Fe)	5.1559 ± 0.4977	8.0800 ± 0.9100	7.4800 ± 0.8400	6.6600 ± 0.7500
Cobalt (Co)	0.0002 ± 0.0808	0.0000 ± 0.1100	0.0100 ± 0.1000	0.0100 ± 0.0900
Nickel (Ni)	0.0029 ± 0.0044	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000
Copper (Cu)	0.0177 ± 0.0110	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000
Zinc (Zn)	0.0560 ± 0.0826	0.0300 ± 0.0000	0.0200 ± 0.0000	0.0300 ± 0.0000
Gallium (Ga)	0.0004 ± 0.0028	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Arsenic (As)	0.0015 ± 0.0029	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Selenium (Se)	0.0002 ± 0.0015	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Bromine (Br)	0.0008 ± 0.0014	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Rubidium (Rb)	0.0137 ± 0.0032	0.0300 ± 0.0000	0.0200 ± 0.0000	0.0200 ± 0.0000
Strontium (Sr)	0.0294 ± 0.0082	0.0400 ± 0.0000	0.0200 ± 0.0000	0.0300 ± 0.0000
Yttrium (Y)	0.0024 ± 0.0017	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Zirconium (Zr)	0.0109 ± 0.0028	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000
Molybdenum (Mo)	0.0010 ± 0.0039	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Palladium (Pd)	0.0004 ± 0.0237	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100
Silver (Ag)	0.0017 ± 0.0279	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100
Cadmium (Cd)	0.0027 ± 0.0294	0.0100 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100
Indium (In)	0.0001 ± 0.0332	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100
Tin (Sn)	0.0050 ± 0.0413	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0200
Antimony (Sb)	0.0103 ± 0.0486	0.0000 ± 0.0100	0.0000 ± 0.0200	0.0000 ± 0.0200
Barium (Ba)	0.0827 ± 0.1566	0.0800 ± 0.0200	0.0800 ± 0.0200	0.0700 ± 0.0200
Lanthanum (La)	0.0521 ± 0.2323	0.0000 ± 0.0600	0.0200 ± 0.0600	0.0100 ± 0.0700
Gold (Au)	0.0004 ± 0.0060	n/a ± n/a	n/a ± n/a	n/a ± n/a
Mercury (Hg)	0.0008 ± 0.0034	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000
Thallium (Tl)	0.0005 ± 0.0033	n/a ± n/a	n/a ± n/a	n/a ± n/a
Lead (Pb)	0.0042 ± 0.0050	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000
Uranium (U)	0.0012 ± 0.0037	n/a ± n/a	n/a ± n/a	n/a ± n/a

Table 4 (*continued*)

	Agricultural soil (continued)			Animal husbandry	
Mnemonic	SOIL10 (1987)	SOIL14 (1987)	SOIL15 (1987)	CATTLE	VIDAIC (1987)
Source type	Cotton Field	Agricultural Tilled Composite	Alfalfa Field	Animal Husbandry Composite	Dairy/Feedlot
Location	Bakersfield/Oildale/Taft		Bakersfield/Oildale/Taft		Visalia
Chloride (Cl^-)	n/a ± n/a	n/a ± n/a	n/a ± n/a	0.7679 ± 0.6953	n/a ± n/a
Nitrate (NO_3^-)	0.0400 ± 0.5700	0.0000 ± 0.4200	0.0400 ± 0.5300	0.0138 ± 0.0566	1.8500 ± 1.6000
Phosphate (PO_4^{2-})	n/a ± n/a	n/a ± n/a	n/a ± n/a	2.5670 ± 1.3980	n/a ± n/a
Sulfate (SO_4^{2-})	0.1600 ± 0.2800	0.0000 ± 0.1500	0.0800 ± 0.1900	0.6155 ± 0.1862	0.7900 ± 0.5700
Ammonium (NH_4^+)	0.0000 ± 0.0100	0.0500 ± 0.0100	0.0700 ± 0.0100	0.0451 ± 0.0652	0.4500 ± 0.4000
Soluble Sodium (Na^+)	0.2100 ± 0.1800	0.1800 ± 0.0800	0.2100 ± 0.0600	0.5487 ± 0.3491	0.4500 ± 0.0400
Soluble Potassium (K^+)	0.1300 ± 0.0500	0.1400 ± 0.0400	0.0300 ± 0.0500	2.4128 ± 0.9670	1.9800 ± 0.2400
Organic Carbon (OC)	3.4500 ± 1.1200	2.2900 ± 1.1200	2.9000 ± 1.7300	18.4483 ± 7.2904	21.7400 ± 2.6200
Elemental Carbon (EC)	0.0000 ± 0.2700	0.1600 ± 0.2000	0.0000 ± 0.2500	0.5571 ± 0.6804	1.2900 ± 0.8400
Total Carbon (TC)	3.4500 ± 1.1521	2.4500 ± 1.1377	2.9000 ± 1.7480	19.0054 ± 7.6461	23.0300 ± 2.7514
Carbonate Carbon (C in CO_3^{2-})	0.5294 ± 0.3757	0.3755 ± 0.2794	0.0070 ± 0.3475	0.3053 ± 0.4876	0.2625 ± 0.0961
Sodium (Na)	n/a ± n/a	n/a ± n/a	n/a ± n/a	0.1754 ± 0.0676	n/a ± n/a
Magnesium (Mg)	n/a ± n/a	n/a ± n/a	n/a ± n/a	1.4263 ± 0.6506	n/a ± n/a
Aluminum (Al)	9.6500 ± 1.3600	11.6900 ± 1.3100	11.1500 ± 1.2500	7.0766 ± 3.4156	2.2900 ± 0.6500
Silicon (Si)	24.9200 ± 2.8000	24.8700 ± 2.7800	29.4200 ± 3.3100	20.2792 ± 8.5581	7.0600 ± 1.6700
Phosporus (P)	0.1700 ± 0.0600	0.2000 ± 0.0200	0.1600 ± 0.0200	2.4752 ± 2.1762	1.0700 ± 0.1200
Sulfur (S)	0.2000 ± 0.0600	0.0800 ± 0.0100	0.0800 ± 0.0100	0.4831 ± 0.1728	0.7500 ± 0.3300
Chlorine (Cl)	0.4700 ± 0.4800	0.0900 ± 0.0100	0.1100 ± 0.0100	0.6930 ± 0.6947	0.6400 ± 0.0700
Potassium (K)	2.2000 ± 0.2500	2.4600 ± 0.2800	2.2700 ± 0.2500	5.0625 ± 0.9952	3.0000 ± 0.3400
Calcium (Ca)	3.7900 ± 0.7500	3.6700 ± 0.4100	2.2300 ± 0.2500	5.3119 ± 1.1952	3.3400 ± 0.3700
Titanium (Ti)	0.5100 ± 0.0700	0.6300 ± 0.0700	0.6100 ± 0.0700	0.3013 ± 0.1151	0.2100 ± 0.0200
Vanadium (V)	0.0300 ± 0.0100	0.0400 ± 0.0100	0.0300 ± 0.0200	0.0019 ± 0.0374	0.0100 ± 0.0100
Chromium (Cr)	0.0300 ± 0.0000	0.0200 ± 0.0000	0.0200 ± 0.0000	0.0007 ± 0.0114	0.0100 ± 0.0000
Manganese (Mn)	0.1100 ± 0.0100	0.1700 ± 0.0200	0.1000 ± 0.0100	0.0758 ± 0.0067	0.0600 ± 0.0100
Iron (Fe)	5.1400 ± 0.6100	7.1400 ± 0.8000	6.1400 ± 0.6900	3.7163 ± 1.6030	2.1600 ± 0.2400
Cobalt (Co)	0.0100 ± 0.0700	0.0200 ± 0.1000	0.0000 ± 0.0900	0.0000 ± 0.0612	0.0000 ± 0.0300
Nickel (Ni)	0.0100 ± 0.0000	0.0000 ± 0.0000	0.0100 ± 0.0000	0.0008 ± 0.0030	0.0000 ± 0.0000
Copper (Cu)	0.0300 ± 0.0100	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0129 ± 0.0046	0.0100 ± 0.0000
Zinc (Zn)	0.0400 ± 0.0000	0.0200 ± 0.0000	0.0200 ± 0.0000	0.0398 ± 0.0160	0.0200 ± 0.0000
Gallium (Ga)	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0005 ± 0.0026	0.0000 ± 0.0000
Arsenic (As)	0.0000 ± 0.0100	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0015 ± 0.0028	0.0000 ± 0.0000
Selenium (Se)	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0002 ± 0.0014	0.0000 ± 0.0000
Bromine (Br)	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0028 ± 0.0024	0.0000 ± 0.0000
Rubidium (Rb)	0.0200 ± 0.0000	0.0200 ± 0.0000	0.0200 ± 0.0000	0.0143 ± 0.0026	0.0100 ± 0.0000
Strontium (Sr)	0.0300 ± 0.0100	0.0400 ± 0.0000	0.0300 ± 0.0000	0.0296 ± 0.0065	0.0300 ± 0.0000
Yttrium (Y)	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0015 ± 0.0017	0.0000 ± 0.0000
Zirconium (Zr)	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0071 ± 0.0039	0.0000 ± 0.0000
Molybdenum (Mo)	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0005 ± 0.0036	0.0000 ± 0.0000
Palladium (Pd)	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0217	0.0000 ± 0.0100
Silver (Ag)	0.0000 ± 0.0200	0.0000 ± 0.0100	0.0000 ± 0.0200	0.0017 ± 0.0255	0.0000 ± 0.0100
Cadmium (Cd)	0.0000 ± 0.0200	0.0000 ± 0.0100	0.0000 ± 0.0200	0.0000 ± 0.0271	0.0000 ± 0.0100
Indium (In)	0.0000 ± 0.0200	0.0000 ± 0.0200	0.0000 ± 0.0200	0.0002 ± 0.0306	0.0000 ± 0.0100
Tin (Sn)	0.0100 ± 0.0300	0.0000 ± 0.0200	0.0000 ± 0.0300	0.0072 ± 0.0385	0.0000 ± 0.0100
Antimony (Sb)	0.0000 ± 0.0300	0.0000 ± 0.0300	0.0000 ± 0.0300	0.0046 ± 0.0448	0.0000 ± 0.0100
Barium (Ba)	0.0700 ± 0.1000	0.0800 ± 0.0800	0.1100 ± 0.1000	0.0569 ± 0.1482	0.0500 ± 0.0400
Lanthanum (La)	0.0200 ± 0.1300	0.0100 ± 0.1100	0.0100 ± 0.1300	0.0811 ± 0.2130	0.0000 ± 0.0500
Gold (Au)	n/a ± n/a	n/a ± n/a	n/a ± n/a	0.0004 ± 0.0048	n/a ± n/a
Mercury (Hg)	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0003 ± 0.0031	0.0000 ± 0.0000
Thallium (Tl)	n/a ± n/a	n/a ± n/a	n/a ± n/a	0.0003 ± 0.0030	n/a ± n/a
Lead (Pb)	0.0200 ± 0.0000	0.0100 ± 0.0100	0.0000 ± 0.0100	0.0024 ± 0.0040	0.0000 ± 0.0000
Uranium (U)	n/a ± n/a	n/a ± n/a	n/a ± n/a	0.0010 ± 0.0035	n/a ± n/a

	Disturbed land				Construction material	
Mnemonic	SALTDEP	SOIL22 (1987)	SOIL23 (1987)	SOIL24 (1987)	CONST	FRCONC (1987)
Source type	Irrigation Canal Drainage	Searles Lake bed sediment	Owens Lake bed sediment	Owens Lake bed alkaline sediment	Building Construction Composite	Freeway Construction Material
Location		Trona	Lone Pine	Lone Pine		Fresno
Chloride (Cl^-)	0.2200 ± 0.1181	n/a ± n/a	n/a ± n/a	n/a ± n/a	0.0210 ± 0.1019	n/a ± n/a
Nitrate (NO_3^-)	0.1109 ± 0.1568	0.0500 ± 0.2900	0.1100 ± 0.5300	0.3800 ± 0.5900	0.0000 ± 0.1017	1.0600 ± 0.0900
Phosphate (PO_4^{2-})	0.0000 ± 0.0000	n/a ± n/a	n/a ± n/a	n/a ± n/a	0.0000 ± 0.0000	n/a ± n/a
Sulfate (SO_4^{2-})	5.0975 ± 0.5286	5.2500 ± 2.2100	1.7000 ± 1.8500	3.6100 ± 2.1300	0.1163 ± 0.1024	1.2500 ± 0.1300
Ammonium (NH_4^+)	0.1143 ± 0.1271	0.0000 ± 0.0000	0.0000 ± 0.0100	0.0000 ± 0.0000	0.0755 ± 0.1172	0.5800 ± 0.0600
Soluble Sodium (Na^+)	2.2176 ± 0.9064	5.5800 ± 1.0100	5.8000 ± 1.8400	10.6300 ± 6.0100	0.0603 ± 0.0387	0.3000 ± 0.0700
Soluble Potassium (K^+)	0.0607 ± 0.0239	0.3700 ± 0.2000	0.6800 ± 0.3200	0.4500 ± 0.1700	0.0210 ± 0.0212	0.1400 ± 0.0600
Organic Carbon (OC)	2.5780 ± 0.9663	1.2100 ± 0.5600	1.2300 ± 1.2700	1.7200 ± 0.9300	2.9017 ± 1.5444	9.2000 ± 4.5800
Elemental Carbon (EC)	0.0595 ± 0.3635	0.1500 ± 0.2600	0.0100 ± 0.2500	0.0000 ± 0.1000	0.3585 ± 0.3735	6.6900 ± 1.8300
Total Carbon (TC)	2.6374 ± 0.9388	1.3600 ± 0.6174	1.2400 ± 1.2944	1.7200 ± 0.9354	3.2602 ± 1.1709	15.8900 ± 4.9321
Carbonate Carbon (C in CO_3^{2-})	0.9148 ± 0.3317	1.9929 ± 0.6753	2.3071 ± 1.2144	2.5321 ± 0.8327	0.5312 ± 0.4109	0.0000 ± 0.2258
Sodium (Na)	1.9573 ± 1.5848	n/a ± n/a	n/a ± n/a	n/a ± n/a	0.6153 ± 0.0894	n/a ± n/a
Magnesium (Mg)	0.7086 ± 0.1391	n/a ± n/a	n/a ± n/a	n/a ± n/a	0.7269 ± 0.1698	n/a ± n/a
Aluminum (Al)	9.7394 ± 2.8788	4.9000 ± 0.5500	5.2600 ± 0.7200	3.1000 ± 0.3500	12.3288 ± 3.7469	7.0000 ± 0.7900
Silicon (Si)	28.4962 ± 8.9460	14.8900 ± 1.7000	19.5200 ± 2.2200	16.4000 ± 1.8500	38.2117 ± 12.2911	19.5400 ± 2.2100
Phosporus (P)	0.0000 ± 0.0674	0.0000 ± 0.0800	0.0700 ± 0.0400	0.0000 ± 0.0500	0.0802 ± 0.0458	0.1000 ± 0.0200
Sulfur (S)	3.5419 ± 2.0069	1.6200 ± 0.4000	0.7000 ± 0.0900	0.9700 ± 0.1100	0.1317 ± 0.0529	0.5700 ± 0.4800
Chlorine (Cl)	0.2814 ± 0.0893	1.2000 ± 0.1300	1.0800 ± 0.3300	1.2700 ± 0.1800	0.0000 ± 0.0735	0.1800 ± 0.1100
Potassium (K)	2.1944 ± 0.4281	2.6600 ± 0.3800	2.5500 ± 0.2900	1.9600 ± 0.2900	3.3043 ± 0.6734	1.9700 ± 0.2500
Calcium (Ca)	4.2514 ± 1.0576	8.5400 ± 1.9300	8.0700 ± 2.4400	7.2200 ± 1.0100	5.1648 ± 1.1624	1.5100 ± 0.1900
Titanium (Ti)	0.4028 ± 0.0367	0.3800 ± 0.0500	0.2700 ± 0.0500	0.2000 ± 0.0400	0.4560 ± 0.0870	0.3600 ± 0.0400
Vanadium (V)	0.0110 ± 0.0256	0.0200 ± 0.0100	0.0200 ± 0.0100	0.0100 ± 0.0100	0.0183 ± 0.0504	0.0200 ± 0.0300
Chromium (Cr)	0.0008 ± 0.0079	0.0100 ± 0.0000	0.0200 ± 0.0100	0.0100 ± 0.0000	0.0039 ± 0.0136	0.0200 ± 0.0000
Manganese (Mn)	0.0743 ± 0.0364	0.0900 ± 0.0100	0.0800 ± 0.0200	0.0600 ± 0.0100	0.1108 ± 0.0141	0.0800 ± 0.0100
Iron (Fe)	4.6795 ± 0.7735	3.1700 ± 0.4700	2.7700 ± 0.4700	2.0300 ± 0.3500	4.5950 ± 0.5694	3.6300 ± 0.4100
Cobalt (Co)	0.0036 ± 0.0734	0.0100 ± 0.0400	0.0100 ± 0.0400	0.0100 ± 0.0300	0.0052 ± 0.0721	0.0000 ± 0.0500
Nickel (Ni)	0.0009 ± 0.0027	0.0000 ± 0.0000	0.0100 ± 0.0000	0.0000 ± 0.0000	0.0041 ± 0.0044	0.0100 ± 0.0000
Copper (Cu)	0.0110 ± 0.0087	0.0100 ± 0.0000	0.0900 ± 0.0100	0.0100 ± 0.0000	0.0131 ± 0.0060	0.0000 ± 0.0000
Zinc (Zn)	0.0158 ± 0.0035	0.0100 ± 0.0000	0.0600 ± 0.0100	0.0100 ± 0.0000	0.0283 ± 0.0088	0.0400 ± 0.0300
Gallium (Ga)	0.0001 ± 0.0020	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0043	0.0000 ± 0.0100
Arsenic (As)	0.0046 ± 0.0025	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0008 ± 0.0048	0.0000 ± 0.0100
Selenium (Se)	0.0000 ± 0.0011	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0010 ± 0.0024	0.0000 ± 0.0000
Bromine (Br)	0.0019 ± 0.0008	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0006 ± 0.0023	0.0000 ± 0.0000
Rubidium (Rb)	0.0126 ± 0.0008	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0162 ± 0.0019	0.0100 ± 0.0000
Strontium (Sr)	0.0462 ± 0.0045	0.0900 ± 0.0200	0.0600 ± 0.0100	0.1100 ± 0.0200	0.0538 ± 0.0041	0.0300 ± 0.0100
Yttrium (Y)	0.0022 ± 0.0010	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0000 ± 0.0000	0.0027 ± 0.0021	0.0000 ± 0.0100
Zirconium (Zr)	0.0087 ± 0.0047	0.0100 ± 0.0000	0.0100 ± 0.0000	0.0000 ± 0.0000	0.0122 ± 0.0027	0.0100 ± 0.0000
Molybdenum (Mo)	0.0054 ± 0.0037	0.0000 ± 0.0000	0.0000 ± 0.0100	0.0000 ± 0.0000	0.0022 ± 0.0059	0.0000 ± 0.0100
Palladium (Pd)	0.0000 ± 0.0168	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0000 ± 0.0100	0.0017 ± 0.0372	0.0000 ± 0.0200
Silver (Ag)	0.0000 ± 0.0196	0.0000 ± 0.0100	0.0000 ± 0.0200	0.0000 ± 0.0100	0.0000 ± 0.0435	0.0000 ± 0.0300
Cadmium (Cd)	0.0012 ± 0.0209	0.0000 ± 0.0100	0.0100 ± 0.0200	0.0000 ± 0.0100	0.0000 ± 0.0458	0.0000 ± 0.0300
Indium (In)	0.0000 ± 0.0234	0.0000 ± 0.0100	0.0000 ± 0.0200	0.0000 ± 0.0100	0.0000 ± 0.0515	0.0000 ± 0.0400
Tin (Sn)	0.0055 ± 0.0294	0.0000 ± 0.0200	0.0900 ± 0.0200	0.0100 ± 0.0100	0.0024 ± 0.0647	0.0000 ± 0.0500
Antimony (Sb)	0.0110 ± 0.0342	0.0000 ± 0.0200	0.0000 ± 0.0300	0.0000 ± 0.0100	0.0132 ± 0.0754	0.0100 ± 0.0600
Barium (Ba)	0.0498 ± 0.1148	0.0600 ± 0.0500	0.0600 ± 0.1100	0.0800 ± 0.0200	0.0862 ± 0.2517	0.1500 ± 0.1900
Lanthanum (La)	0.0117 ± 0.1623	0.0200 ± 0.0700	0.0000 ± 0.1300	0.0100 ± 0.0600	0.0024 ± 0.3596	0.0000 ± 0.2200
Gold (Au)	0.0000 ± 0.0035	n/a ± n/a	n/a ± n/a	n/a ± n/a	0.0005 ± 0.0078	n/a ± n/a
Mercury (Hg)	0.0006 ± 0.0024	0.0000 ± 0.0000	0.0000 ± 0.0100	0.0000 ± 0.0000	0.0017 ± 0.0052	0.0000 ± 0.0100
Thallium (Tl)	0.0000 ± 0.0023	n/a ± n/a	n/a ± n/a	n/a ± n/a	0.0006 ± 0.0050	n/a ± n/a
Lead (Pb)	0.0010 ± 0.0032	0.0000 ± 0.0000	0.0100 ± 0.0100	0.0000 ± 0.0000	0.0084 ± 0.0055	0.0000 ± 0.0100
Uranium (U)	0.0029 ± 0.0024	n/a ± n/a	n/a ± n/a	n/a ± n/a	0.0018 ± 0.0054	n/a ± n/a

paved and unpaved road dust and agricultural soil profiles.

The Ca abundance (2.5±0.8%) in the agricultural soil profile is 30–50% lower than in other profiles. Soil composition, soil amendments, and leaching of water-soluble calcium carbonate by irrigation may positively or negatively affect Ca abundances in agricultural soil. Total carbon (3.2±1.8%) in agricultural soil is similar to that of unpaved road dust and construction soil, but 60% less than its abundance in paved road dust (7.9±4.7%). In addition, a higher carbon content, nutrient-related chemical species (PO_4^{2} , P, K^+, and K) as well as Cl , Cl, Ca, Br, Ag, and La are more abundant in the animal husbandry profile. Phosphorus (P) and phosphate (PO_4^{2}) are also abundant in feedlot profiles, with 5.7±2.4% P in Fresno county soil (FDCATFL2) and 4.1±1.0% PO_4^{2} in Kern county soil (FDCATFL1). High P and PO_4^{2} abundances occur in the dairy profile (FDCATDR), but they are 56–77% of the feedlot (FDCATFL) abundances.

The pyrolyzed carbon (OP) abundance ranges from 0.25±0.28% in the unpaved road dust profile to 1.6±1.1% in the animal husbandry profile. The OP abundance in the animal husbandry profile is *Ca* 50% higher than its abundance in paved road dust and 3–7 times higher than in the other profiles. Yu et al. (2002) found that OP increases with the water-soluble organic carbon (WSOC) content, and that WSOC accounts for 13–66% of pyrolized carbon. More of the water-soluble polar compounds are expected in animal waste than in other sources, and the OP fraction may be a useful marker for these and other sources with polar organic compounds (Yu et al., 2002). Elevated OP fractions are accompanied by higher OC3 abundances in both the animal husbandry and paved road dust profiles.

3.2. Comparisons with previous SJV profiles

Composite geological profiles from the 1997 FDCS can be compared with earlier fugitive dust profiles acquired in the SJV during 1987 (Houck et al., 1989) in Table 4. OC and EC were measured by the same IMPROVE method for the 1987 samples, but the eight carbon fractions, Cl , PO_4^{2} , Na, Mg, Au, Tl, and U abundances were not reported. For urban paved road dust, FDPVRD1 is similar to the 1987 paved road dust profiles from Fresno (SOIL03), Visalia (SOIL08), and Bakersfield/Oildale/Taft (SOIL12). Large differences are found for carbon. OC (9.5±2.6%) from FDPVRD1 is 50% of the 1987 Fresno (SOIL03) profile abundance (19.5±4.7%), but similar to those found in the 1987 Visalia (11.5±1.8%) and Bakersfield/Oildale/Taft (13.5±1.4%) profiles. EC (1.7±1.2%) from FDPVRD1 is 40% lower than the 1987 Fresno (SOIL03) profile (2.7±1.4%) but is similar to the 1987 Visalia (1.7±1.1%) abundance. Fugitive dust markers such as Al, Si, K, Ca, and Ti have similar abundances for the 1987 and 1997 profiles. Trace elements (Cu, Rb, Sr, Zr, and Ba) in FDPVRD1 are twice those from the 1987 profiles. The most noticeable difference is the reduction of Pb from 0.26±0.03% in the SOIL03 profile to 0.016±0.003% in the FDPVRD1 profile. Twenty years after Pb was phased out of gasoline, concentrations of Pb in paved road dust have decreased by over one order of magnitude. Carbonate carbon is 0.22±0.27% in Fresno paved road dust (SOIL08) and 1.8±0.6% in FDPVRD1.

For unpaved road dust (UNPVRD), the Si abundances differ the most, with 22.5±2.5% for Visalia (SOIL07) and 32.9±11.8% in UNPVRD. Carbonate carbon is only 0.05±0.15% in Bakersfield unpaved parking lot dust (SOIL13) and 1.2±0.3% in UNPVRD. Other chemical abundances are similar with ±20–40% differences among the six unpaved road dust profiles.

The composite agricultural soil (AGRI) profile is similar to the Visalia cotton/walnut field (SOIL04) and grape field (SOIL05) profiles, Bakersfield/Oildale/Taft cotton field (SOIL09 and 10), composite agricultural tillage (SOIL14), and alfalfa field (SOIL15) profiles. The Cl abundance is an exception, being undetectable (0.0006±0.05%) in AGRI and 0.47±0.48% in SOIL10. The carbonate carbon abundance exceeds 0.5% only in the SOIL10 and AGRI profiles.

The animal husbandry (CATTLE) profile derived from Fresno, Kings, and Kern county samples differs from the 1987 Visalia profile (VIDAIC). The largest difference is for NO_3 , which is undetectable in CATTLE but constitutes 1.85±1.6% in VIDAIC. OC is 118% higher and EC is 230% higher in VIDAIC as compared to CATTLE. The largest difference is for Si, with 20.3±8.6% in CATTLE and 7.1±1.7% in VIDAIC. The Al abundance is 7.1±3.4% in CATTLE and 2.3±0.6% in VIDAIC. Other abundances such as P, Ca, and Fe are 1.6–2.3 times abundances in the 1997 profile (CATTLE). Many trace elements were not detected in the 1987 profiles. These differences reflect inherent variabilities in dairy and feedlot soils.

Disturbed land profiles from irrigation canal drainages (SALTDEP) are only comparable to 1987 samples from outside the SJV at Searles Dry Lake (SOIL22) and Owens Dry Lake (SOIL23 and 24). Soluble Na^+ is 2.2±0.9% in SALTDEP and 10.6±6% in SOIL24. Al and Si abundances in SALTDEP are 2–3 times those of SOIL24, with the exception of Ca that is at ~60% of its SOIL24 abundance. Carbonate carbon in SALTDEP (0.91±0.33%) is less than half the abundances of the 1987 profiles, which range from 2.0±0.67% in SOIL22 to 2.5±0.83% in SOIL24.

The 1997 construction dust profile (CONST) from Madera and Fresno county samples differs from the 1987 Fresno freeway construction dust profile (FRCONC). OC, EC, NO_3^-, and SO_4^{2} are 3–19 times higher in the 1987 profile. On the other hand, major geological elements (Al, Si, K, Ca, and Fe) are higher in CONST. Ca abundances are $5.2 \pm 1.2\%$ in CONST and only $1.5 \pm 0.19\%$ in FRCONC. Carbonate carbon is $0.53 \pm 0.41\%$ in CONST and undetectable ($0 \pm 0.23\%$) in FRCONC.

4. Summary and conclusions

The systematic composite source profile method developed in this study resulted in 25 composite source profiles with different chemical abundances and variabilities, in addition to the 47 individual fugitive dust profiles and 2 replicate resuspension profiles from which they were derived. Duplicate laboratory resuspension sampling and triplicate field sampling from the same agricultural fields resulted in similar source profiles. For most species, differences in abundances were within analytical uncertainties. Over 90% of the paired differences were within $\pm 3\sigma$ for Level III (variations attributable to sampling from different locations). Weighted correlations decreased with continued compositing beyond Level III. At Level IV, the two animal husbandry profiles (dairy vs. feedlot soils) showed low correlation ($r = 0.49$).

Large variabilities were found among subtypes within each source type. Differences were found among six composited geological source profiles for common emission inventory categories. OC1, EC2, carbonate carbon, Zn, Ga, Zr, Sn, Ba, and Pb abundances in the paved road dust profile differed most from the other composite profiles. NO_3 , Cr, and Ni abundances were most distinctive in the unpaved road dust profile. Na^+, Na, S, SO_4^2 , Cl , Cl, As, Mo, Cd, Sb, and U abundances characterized the salt deposit profile. Al, Si, Ca, Ti, V, Mn, Co, Hg, Pd, Rb, Sr, Tl, and Se abundances marked the construction dust profiles. Agricultural soil contained a lower Ca abundance than other profiles. Carbon fractions (OC2, OC3, OC4, OP, EC1, and EC3), PO_4^2 , P, K^+, K, Cl , Cl, Ca, Br, Ag, and La marked the animal husbandry profile.

The systematic sample compositing scheme developed in this study provides a framework for future source profile composites. Student *t*-test probabilities and R/U ratios are objective measures of similarity and difference that can be used to determine which samples should or should not be included in averages intended to represent larger populations. Inherent variabilities in source subtypes (such as urban vs. rural paved roads, agricultural vs. residential unpaved roads, and feedlot vs. dairy) require a large number of samples from different locations to estimate average abundances and their standard deviations. Multiple samples from the same location are not as useful as the same number of samples from similar activities at different locations. Less variability was found among the agricultural soils from five different crops and between the two construction soils from two separate counties. Sensitivity tests on these source type and source subtype profiles will be performed to examine collinearity among the profiles and to make final selections for input to CMB receptor modeling.

Compared with the previous geological dust profiles acquired in 1987, the 1997 profiles show large differences for animal husbandry, construction, and salt deposits from canal drainage and dry lake bed, and smaller profile differences for agricultural soil, paved road dust, and unpaved road dust. This implies that more samples from dairy/feedlot, construction, and salt deposits need to be acquired to obtain representative source profiles in central California.

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