



Description and Analytical Results for Deposited Dust Samples from a Two-Year Monitoring Program Near Deer Trail, Colorado, USA, 2006–2007

By Marith Reheis, Jeff Honke, Paul Lamothe, and Eric Fisher

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
Area		
square meter (m ²)	10.76	square foot (ft ²)
square centimeter (cm ²)	0.1550	square inch (in ²)
Mass		
gram (g)	0.03527	ounce, avoirdupois (oz)

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)

Analytical Results for Deposited Dust Samples from a Two-Year Monitoring Program Near Deer Trail, Colorado, USA, 2006–2007

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Abstract

Biosolids reclaimed from municipal wastewater have been applied since 1993 on nonirrigated farmland and rangeland east of Deer Trail, Colo., by Metro Wastewater Reclamation District of Denver. The U.S. Geological Survey has monitored ground water at this site since 1993, and began monitoring the biosolids, soils, and stream sediments in 1999. To investigate the possible effects of airborne dust blowing from the application fields, passive dust samplers were deployed in 2006 and 2007. These samplers measured the quantity and composition of dust being deposited downwind of a farmed field where biosolids had been applied, compared to a farmed field upwind of the application area.

The dust-deposition rates and dust compositions measured at the two study sites are consistent with rates and compositions measured elsewhere in Utah, Nevada, and California using the same methods and equipment. Higher deposition rates were measured at the biosolids site compared to the control site during 2006. Higher deposition rates at both sites appear to be associated with episodes of cultivation and harvest during dry periods. No consistent differences in elements likely to be associated with biosolids disposal were detected between the sites. However, the contents of copper, lead, and zinc in the dust samples are generally much higher than average values of these elements in crustal rocks and sediments. Such values for dust samples are consistent with measurements on modern dust samples from southern Nevada and California and probably reflect inputs from regional urban and manufacturing activities.

Introduction

Application of biosolids reclaimed from municipal wastewater has been conducted since 1995 on nonirrigated farmland and rangeland east of Deer Trail, Colo., by Metro Wastewater Reclamation District of Denver (fig. 1). The U.S. Geological Survey (USGS) has monitored ground water at this site since 1993 (Yager and Arnold, 2003), and began a more comprehensive monitoring program of ground water as well as the biosolids, soils, and stream sediments in 1999 (for example, Yager and others, 2004; Crock and others, 2008). To address additional concerns of citizens and stakeholders regarding possible effects of airborne dust blowing from the application fields, a two-year study using passive dust samplers at two sites was conducted in 2006 and 2007. This study monitored the quantity and composition of dust being deposited downwind of a farmed field where biosolids had been applied, compared to a farmed field upwind of the application area.

Methodology

Deposited dust in this study was measured using passive dust-trap samplers following the design and protocols of standard samplers used in several long-term monitoring studies conducted by the USGS in southern Nevada, southern California, and southeastern Utah (Reheis and Kihl, 1995; Reheis, 1997, 1999, 2003). Briefly, the trap consists of a coated angel-food cake pan mounted on a post about 2 m above the ground. Glass marbles rest on metal mesh that is fitted into the pan so that it rests 3–4 cm below the rim. The 1-cm² metal mesh consists of stainless steel wire which is resistant to weathering and does not constitute a source of contamination for the dust samples. The samples integrate wet (sediment and solutes contained in precipitation) and dry deposition (dust) during the period of accumulation. At each sampling site, four traps were constructed, spaced about 10 m apart, and the samples from the four traps were combined for analysis. Samples are retrieved by washing the pan, screen, and marbles using deionized water and collecting the sediment and water in polyethylene bottles. For details on trap construction, sample collection, and analytical procedures, see Reheis and Kihl (1995) and Reheis (1999, 2003).

The two sample sites (fig. 1) were selected on the basis of several criteria, including location adjacent to and downwind (east) of actively tilled and cultivated fields with similar crops, surface soils with similar properties formed on similar parent material (loess or re-deposited loess), and land that was vegetated and not likely to be plowed or otherwise disturbed. In addition, sites were chosen that are not immediately downwind of commonly used gravel roads, to avoid contamination with dust generated by vehicle traffic. All traps were located within 2 to 20 m from the edges of farmed fields. The control site, DT-1 (NAD83 datum: latitude 39°27.581' N, longitude 103°53.909' W), was located about 3.5 km east of Interstate 70 near the town of Agate, on the east edge of cultivated fields that slope gently (about 3°) to the southwest. A frequently traveled county gravel road passes 0.5 km north of the site and an infrequently traveled gravel road is about 100 m east of the site. The site lies on soil mapped as Weld loam (Soil Conservation Service, 1966), which typically consists of deep soils with loam to silt loam to silty clay textures developed on loess deposits. The biosolids site, DT-2 (latitude 39°30.183' N, longitude 103°43.815' W), was located 1.5 km west of the east boundary of the south property owned by Metro Wastewater Reclamation District of Denver, between cultivated fields to the west and east where biosolids are infrequently applied (no applications occurred during the sampling period). A county gravel road passes 0.4 km north of the site and an infrequently traveled gravel road lies about 0.6 km to the east. The site lies on a stream terrace with little or no slope. The soil is mapped as Fort Collins loam with loam to silt loam textures, composed of mixed alluvium derived from loess and fine-grained sandstone (Soil Conservation Service, 1966).

Dust samples accumulated in the dust traps for periods of several weeks to several months, beginning in February 2006 (table 1). Samples were collected more frequently during the typically more dusty periods of late winter and spring, generally at intervals of 3–4 weeks. Additional samples were collected in late summer (August 2006 and September 2007), and these samples represent accumulation since the previous April and May, respectively. Samples collected in early February 2007 represent accumulation since the previous August.

Laboratory Analyses

In the laboratory, the dust samples, suspended in water, were dried at about 35°C in large evaporating dishes and coarse organic material floating on the surface was removed. A split was removed from each sample for analysis of organic and inorganic carbon using coulometric techniques (table 1) (Engleman and others, 1985). The entire remaining sample (unless very large, in which case some material was reserved and not further analyzed) was then used to measure soluble-salt content by electroconductivity (Jackson, 1958). Following this procedure, organic

matter was removed using hydrogen peroxide and particle size was measured using a laser particle-size analyzer (McCave and Syvitski, 1991). Calcium carbonate was not removed; thus, the particle size distribution may include particles of calcite as well as aggregates of smaller particles. The remaining sample was separated by wet sieving into the sand (2 mm to 53 μm diameter) and silt-plus-clay (less than 53 μm) fractions. The elemental contents of the less-than-53- μm fractions of five of the processed dust samples were analyzed using inductively coupled plasma-atomic emission spectroscopy (ICP-AES) and mass spectrometry (ICP-MS) (table 2). For information on these analytical techniques and their levels of precision and accuracy, refer to Briggs and Meier (1999) for ICP-MS, and to Briggs (1996) for ICP-AES. It is possible that some elements that are strongly associated with water-soluble phases in dust samples may have been partially removed (for example, As and Na; Reynolds and others, 2007) because geochemical analysis was performed after leaching with deionized water for the electroconductivity analysis.

Dust-deposition rates (table 3) were calculated on the basis of the dry weight of the total sample after coarse organic material was removed. The organic contents of the samples are reported in table 1, but because these contents fluctuate greatly due to deposition of small particles of wind-borne plant and insect fragments, the deposition rates of the mineral dust and dust components are calculated on an organic-free basis. To obtain deposition rates of a given component, the sample weight is divided by the pan's surface area and by the number of days of accumulation of that sample, then multiplied by the weight percent of the component of interest; the results are reported in $\text{g}/\text{m}^2/\text{day}$.

Discussion and Results

Dust composition and deposition rates are influenced by many factors, including type and composition of dust source, distance from source, climate, wind speed, and human land use. The intent of this study was to provide basic information on dust deposition and composition in east-central Colorado, and to compare dust characteristics between a control site affected by standard agricultural practices and a site having similar land use but with the addition of biosolids applications nearby. Assuming equivalent land practices, we expected deposition rates of most particle sizes, calcium carbonate (CaCO_3), and soluble salts at the two sites to be similar. According to Crock and others (2008), elements of particular interest that might record a biosolids signature include bismuth, copper, silver, mercury, and phosphorus.

Total weights of mineral (non-organic) dust at the two sites during sampling periods showed that more dust was usually deposited at the biosolids site (DT-2), especially during the first year (fig. 2A). Organic contents of the dust samples (table 1) varied somewhat at the control site (DT-1), and showed much larger variation through time at the biosolids site. Sample particle size was less variable; the samples from both sites were mostly silt loams, with a few finer-grained samples that were silty clay loams or clay loams.

Dust samples at the control site tended to be higher in soluble-salt contents (fig. 2C) and three samples were higher in CaCO_3 (fig. 2B). CaCO_3 contents were generally very low, and in many cases were too low to measure using our instrumentation. The results for soluble salts were unexpected. A possible explanation is that the salt content of dust at the control site was enhanced by the site's closer proximity to Interstate 70 and associated snow-removal operations. However, examination of the Colorado Department of Transportation's records of the times of salt application to this stretch of highway shows no direct correlation to peaks in salt content at DT-1.

Dust deposition rates (table 3) were usually higher at the biosolids site than at the control site. Sand, silt, and clay were deposited at much higher rates at the biosolids site from February 2006 through February 2007 (figs. 3A and 3B); after this time, the rates at the two sites were more similar. The distinct peaks in sand deposition at the biosolids site suggest that local wind erosion

caused sand to saltate along the ground surface, at times reaching the 2-m height of the dust pans; such saltation would also increase the production and deposition of silt and clay dust particles. There is a notable association at both sites between higher dust-deposition rates and episodes of cultivation and harvesting of adjacent fields. Soluble-salt deposition rates (fig. 3C) were similar at the two sites despite the higher concentration of salts at DT-1, because the overall amount of dust deposited at DT-2 was greater.

The dust-deposition rates measured east of Deer Trail are generally similar in magnitude to rates measured using the same equipment and techniques at sites in east-central Utah and in southern Nevada and southern California (figs. 3B and 3C) (Reheis, 2003; M. Reheis, U.S. Geological Survey, unpub. data, 2003–2007). However, deposition rates of silt plus clay at site DT-1 are most similar to rates at relatively undisturbed desert and rangeland sites, whereas the higher rates measured at DT-2 during 2006 are most similar to rates at disturbed sites in Utah and California where cultivation has occurred or where sand-transport rates are very high.

Elemental compositions of five dust samples show little overall difference between sites DT-1 and DT-2 (fig. 4 and table 2). In general, samples from the same site taken during different intervals show as much variability in composition as samples from different sites. For example, phosphorus exhibits both high and low values in samples at both sites (fig. 4A), as do copper and zinc (fig. 4B). Manganese, a common element derived from soils and rocks, and strontium, commonly associated with CaCO_3 , appear to be consistently higher at the control site, possibly due to minor differences in local soil composition. The contents of copper, lead, and zinc in the dust samples are generally much higher than average values of these elements in crustal rocks and sediments (fig. 4B) (Krauskopf and Bird, 1995). Such values for dust samples are consistent with measurements on modern dust samples from southern Nevada and California (Reheis and others, 1999), and probably reflect inputs from regional urban and manufacturing activities. From these five samples there appears to be no consistent difference between the sites in the contents of bismuth, copper, silver, and phosphorus, elements that may record a biosolids signature (Crock and others, 2008).

In summary, the dust-deposition rates and dust compositions measured at the two study sites are consistent with rates and compositions measured elsewhere in Utah, Nevada, and California. The higher deposition rates measured at site DT-2 during 2006 were most likely associated with episodes of cultivation and harvest during dry periods. No consistent differences between sites in elements likely to be associated with biosolids disposal were detected.

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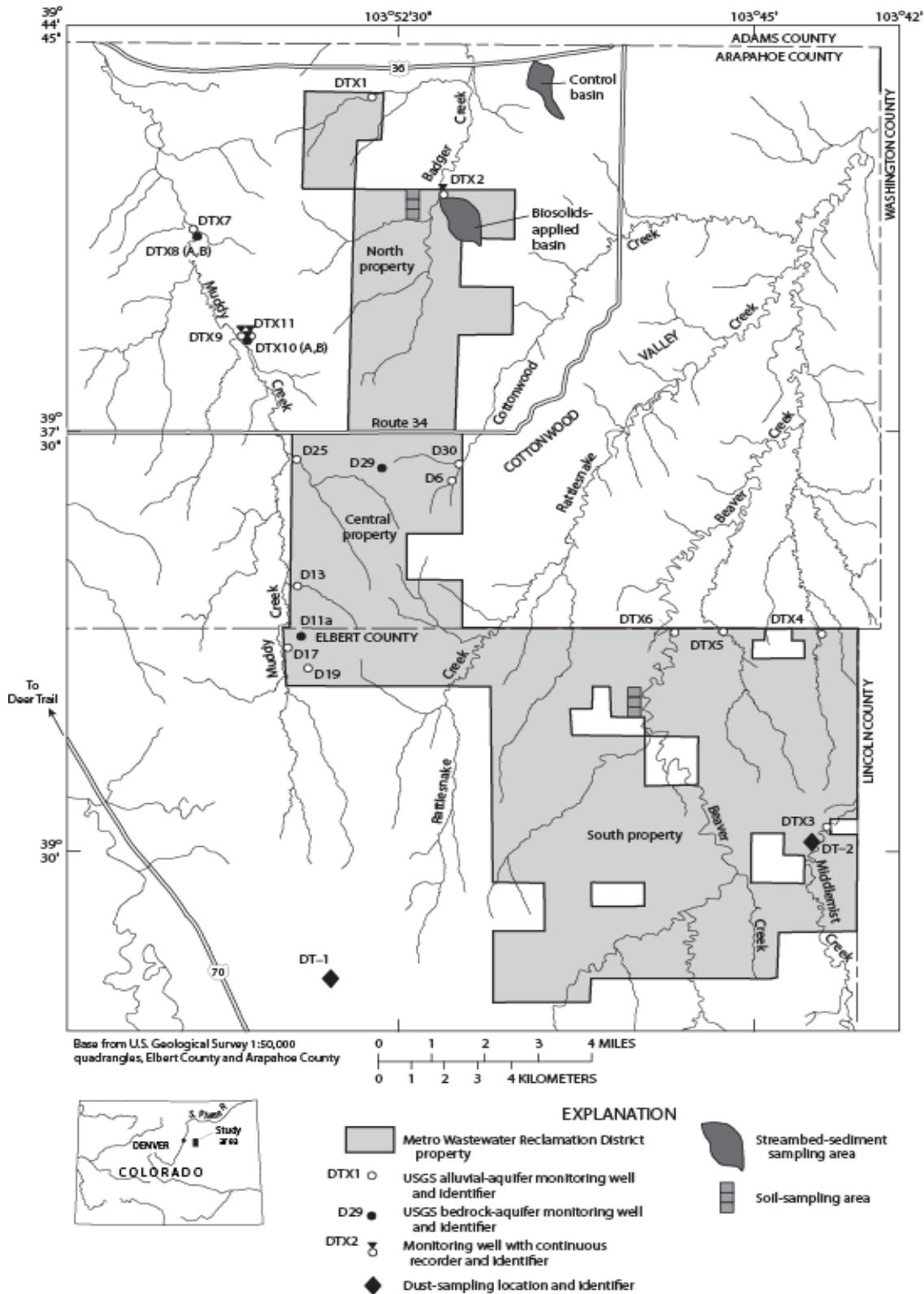


Figure 1. Metro Wastewater Reclamation District property, including locations of dust trap sites DT-1 (control site) and DT-2 (biosolids site), as well as locations of monitoring wells.

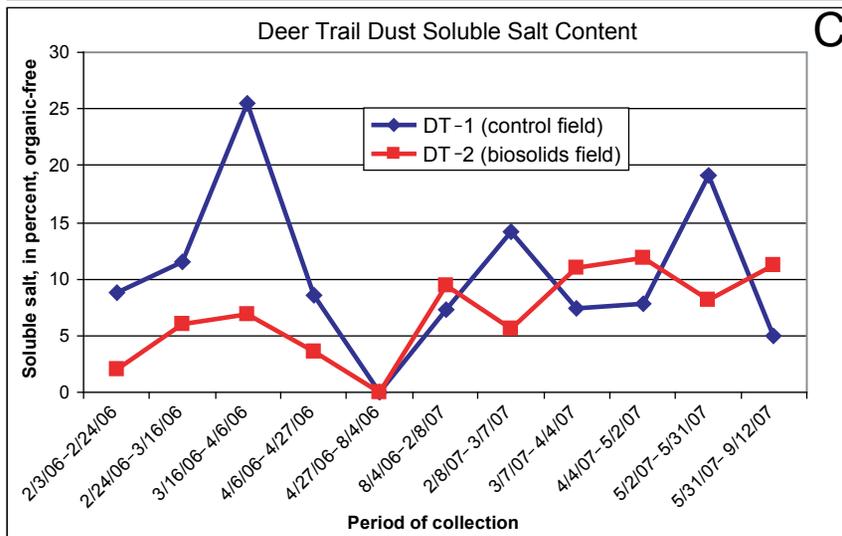
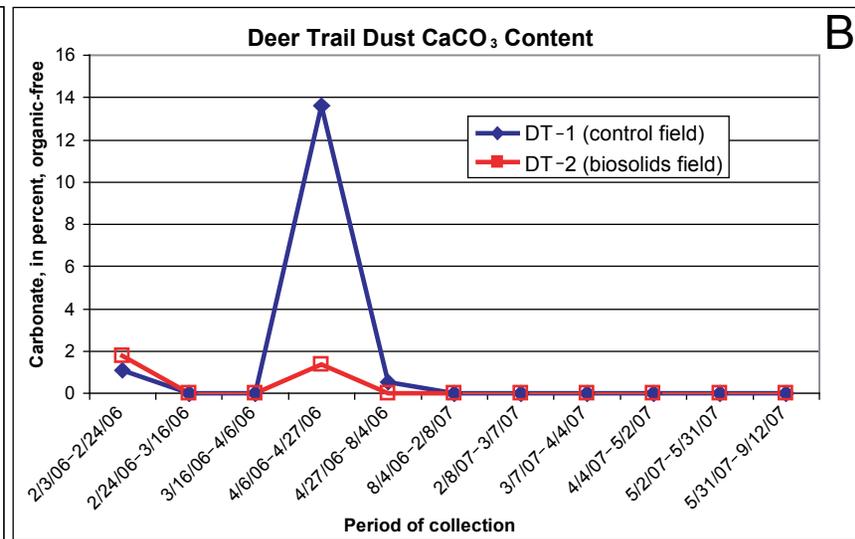
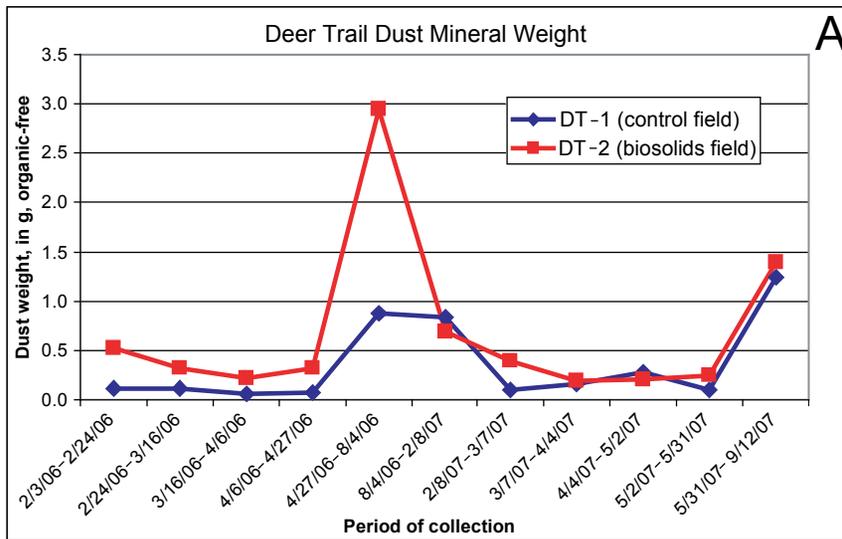


Figure 2. Contents of mineral dust samples during collection intervals. A, Mineral weight of dust samples (organic material excluded). B, CaCO₃ content. C, Soluble salt content.

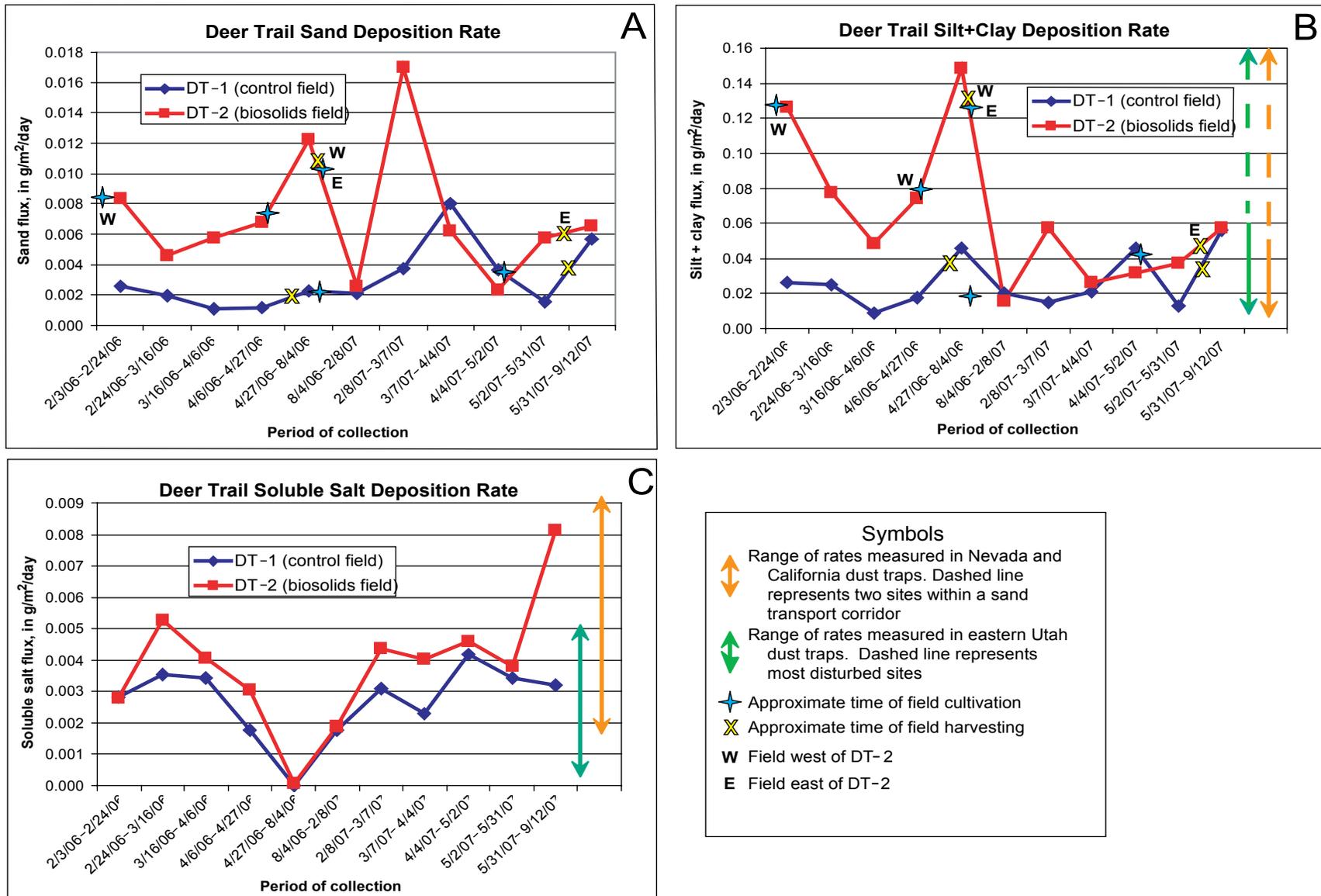


Figure 3. Deposition rates ($\text{g/m}^2/\text{day}$) of mineral dust samples during collection intervals. A, Sand deposition rate. Approximate dates of cultivation of the agricultural fields adjacent to the control and biosolids sites are noted. B, Silt plus clay deposition rate. C, Soluble salt deposition rate. On B and C, a range of deposition rates measured using the same type of marble trap at sites in Utah and Nevada and California (Reheis, 2003; M. Reheis, U.S. Geological Survey, unpub. data, 2003-2007) are shown for comparison.

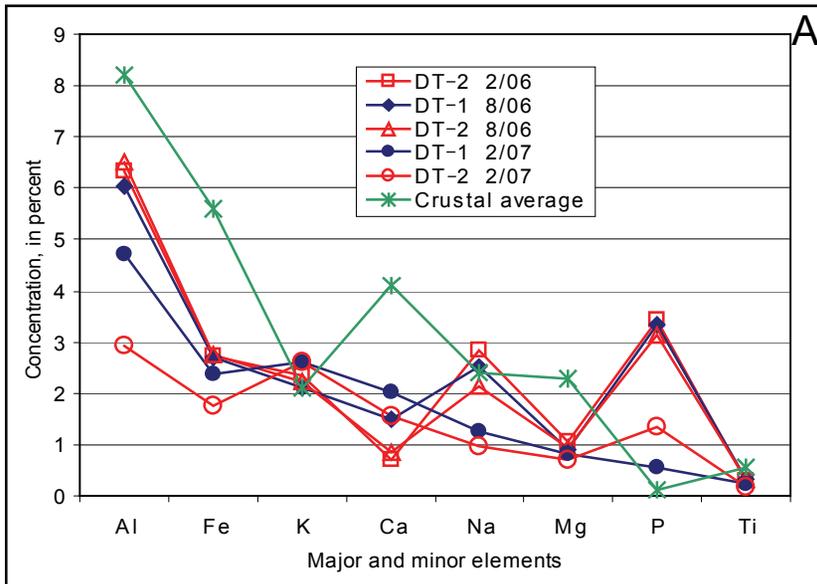


Figure 4. Elemental composition of five dust samples measured by ICP-AES and ICP-MS, compared to composition of average crust (data from Krauskopf and Bird, 1995). *A*, Major and minor elements. *B*, Trace elements.

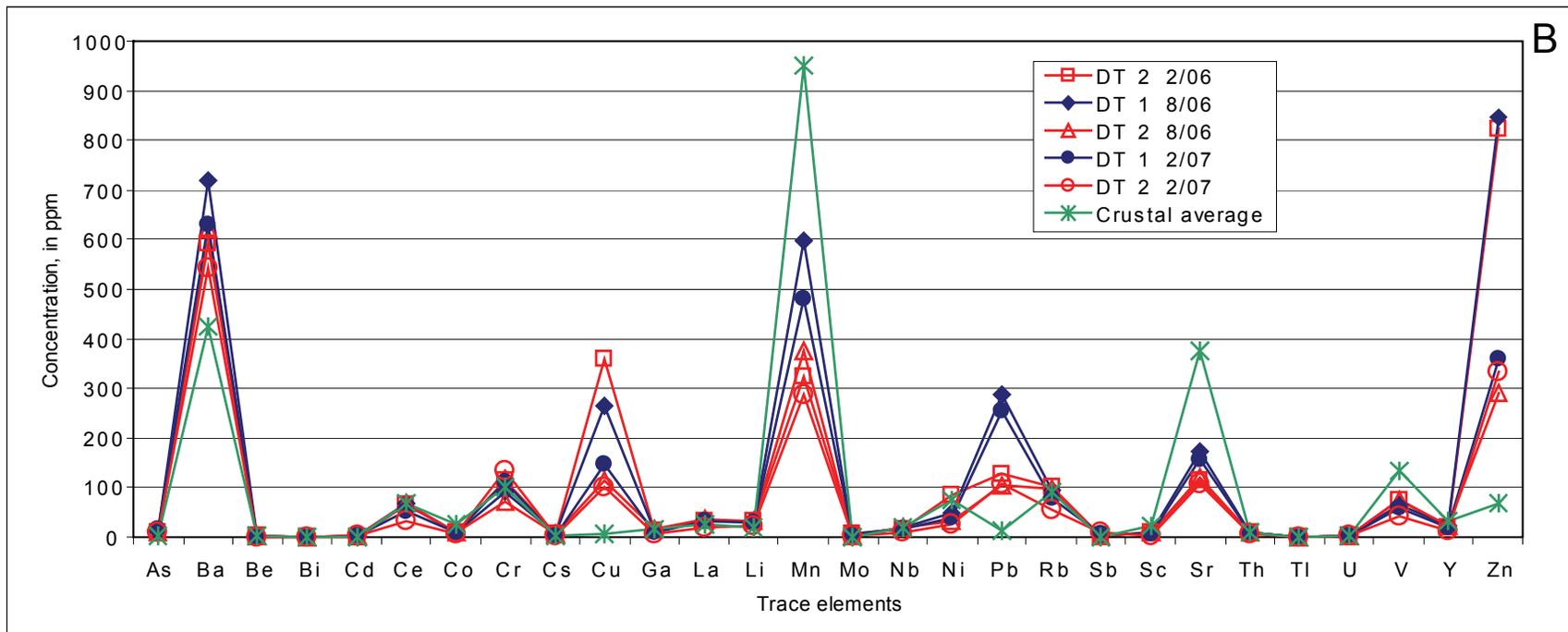


Table 1. Collection intervals and physical and chemical measurements of dust samples.

Site no. ¹	Days out	No. days	Org. C (%)	CaCO ₃ (% total)	CaCO ₃ (org.-free %)	Salts (% total)	Salts (org.-free%)	Mineral wt. (g)	Mineral wt. (org.-free)	<2mm (%)	Percent of <2mm fraction		
											Sand	Silt	Clay
DT-1	2/3/06-2/24/06	21	18.1	0.8	1.1	6.1	8.8	0.18	0.124	100.00	8.85	77.20	13.95
DT-1	2/24/06-3/16/06	20	7.7	0.0	0.0	9.9	11.4	0.13	0.113	100.00	7.19	74.91	17.90
DT-1	3/16/06-4/6/06	21	12.3	0.0	0.0	20.1	25.6	0.07	0.052	100.00	10.93	71.85	17.22
DT-1	4/6/06-4/27/06	21	16.8	9.7	13.6	6.1	8.6	0.11	0.080	100.00	6.39	69.97	23.64
DT-1	4/27/06-8/4/06	99	11.9	0.4	0.5	0.0	0.0	1.10	0.873	100.00	4.78	76.77	18.45
DT-1	8/4/06-2/8/07	187	13.3	0.0	0.0	5.6	7.3	1.08	0.829	100.00	9.57	73.23	17.20
DT-1	2/8/07-3/7/07	27	16.3	0.0	0.0	10.1	14.1	0.15	0.109	100.00	19.98	72.77	7.26
DT-1	3/7/07-4/4/07	28	19.1	0.0	0.0	5.0	7.4	0.24	0.160	100.00	28.04	42.76	29.20
DT-1	4/4/07-5/2/07	28	15.5	0.0	0.0	5.7	7.8	0.38	0.277	100.00	7.33	56.16	36.51
DT-1	5/2/07-5/31/07	29	10.0	0.0	0.0	15.8	19.2	0.12	0.096	100.00	10.52	74.13	15.35
DT-1	5/31/07-9/12/07	104	12.7	0.0	0.0	3.9	4.9	1.59	1.239	100.00	9.19	71.36	19.45
DT-2	2/3/06-2/24/06	21	3.8	1.7	1.8	1.9	2.0	0.57	0.533	100.00	6.19	75.67	18.14
DT-2	2/24/06-3/16/06	20	8.8	0.0	0.0	5.1	6.0	0.38	0.321	100.00	5.57	60.62	33.82
DT-2	3/16/06-4/6/06	21	8.6	0.0	0.0	5.9	6.9	0.27	0.227	100.00	10.60	66.79	22.61
DT-2	4/6/06-4/27/06	21	11.1	1.1	1.3	2.9	3.6	0.40	0.326	100.00	8.38	70.04	21.58
DT-2	4/27/06-8/4/06	99	7.7	0.0	0.0	0.0	0.1	3.39	2.937	100.00	7.60	75.36	17.04
DT-2	8/4/06-2/8/07	187	11.9	0.0	0.0	7.5	9.4	0.87	0.693	100.00	14.14	72.52	13.34
DT-2	2/8/07-3/7/07	27	0.0	0.0	0.0	5.6	5.6	0.39	0.391	100.00	22.89	66.41	10.70
DT-2	3/7/07-4/4/07	28	30.0	0.0	0.0	5.3	11.0	0.39	0.188	100.00	19.19	52.23	28.58
DT-2	4/4/07-5/2/07	28	15.5	0.0	0.0	8.7	11.9	0.27	0.199	100.00	6.84	57.30	35.86
DT-2	5/2/07-5/31/07	29	9.9	0.0	0.0	6.8	8.2	0.30	0.248	100.00	13.46	71.57	14.97
DT-2	5/31/07-9/12/07	104	21.2	0.0	0.0	7.1	11.3	2.18	1.384	100.00	10.23	72.73	17.04

¹ DT-1, control site; DT-2, biosolids site

Table 2. Elemental analytical data for five dust samples.

[Analytical method used is noted for each element: MS = ICP-MS, AES = ICP-AES]

Element	Al	Fe	K	Ca	Na	Mg	P	Ti	Ag	As	Ba	Be	Bi	Cd	Ce	Co	Cr	Cs	Cu
	%	%	%	%	%	%	%	%	ppm										
Method	AES	MS																	
Sample no.¹																			
DT-2 2/06	6.34	2.73	2.34	0.705	2.83	1.07	3.44	0.3021	<1	11.1	590	1.7	0.63	1.2	64.8	10.8	114	5.8	360
DT-1 8/06	6.05	2.70	2.11	1.5	2.51	0.918	3.33	0.3172	<1	11.6	720	1.8	0.47	3.1	70	10.2	91.5	5	264
DT-2 8/06	6.52	2.77	2.24	0.845	2.13	0.943	3.15	0.3087	<1	8.2	621	2.1	0.46	2	69.7	9.4	70.8	6	115
DT-1 2/07	4.71	2.37	2.61	2.03	1.25	0.832	0.571	0.244	<1	15.4	630	1.6	0.43	2.6	52.9	9.1	111	4.3	147
DT-2 2/07	2.93	1.75	2.6	1.56	0.954	0.702	1.36	0.168	<1	10.7	541	0.93	0.32	2.9	31.6	6	134	3.1	102
Element	Ga	La	Li	Mn	Mo	Nb	Ni	Pb	Rb	Sb	Sc	Sr	Th	Tl	U	V	Y	Zn	
	ppm																		
Method	MS	MS	MS	AES	MS														
Sample no.																			
DT-2 2/06	14.4	33.6	32.9	323	5.6	17	86.3	127	100	3.6	8.8	114	10.7	0.87	3.03	74.6	18.6	823	
DT-1 8/06	14.3	36.9	28.1	597	3.9	18	50.2	286	94.9	3	8.7	172	11.4	0.73	3.06	65.6	23.4	847	
DT-2 8/06	15.1	36.4	32.6	375	2.1	18	32.4	103	98.6	2	9.3	121	11	0.7	2.57	76.7	22.5	292	
DT-1 2/07	11.2	32.3	27.8	482	5.8	15	37.8	254	78.9	5.6	6.9	157	10.9	0.58	2.78	60.4	20.7	359	
DT-2 2/07	7.4	19.4	22.7	287	4.7	9	25.8	108	56.5	11.1	4.4	108	6.92	0.39	1.77	41.2	13.2	334	

¹ Samples arranged in chronological order. Numbers (for example, 2/06) following site designation indicate month and year of collection.

Table 3. Daily deposition rates of dust components.

Site no.	Days out	Dust + organics ¹	Daily deposition rate (g/m ² /day)					
			Dust	CaCO ₃	Soluble salt	Sand	Silt	Clay
DT-1	2/3/06-2/24/06	0.0465	0.0320	0.0003	0.0028	0.0026	0.0225	0.0041
DT-1	2/24/06-3/16/06	0.0355	0.0308	0.0000	0.0035	0.0020	0.0204	0.0049
DT-1	3/16/06-4/6/06	0.0170	0.0134	0.0000	0.0034	0.0011	0.0072	0.0017
DT-1	4/6/06-4/27/06	0.0291	0.0206	0.0028	0.0018	0.0012	0.0132	0.0045
DT-1	4/27/06-8/4/06	0.0602	0.0479	0.0003	0.0000	0.0023	0.0368	0.0088
DT-1	8/4/06-2/8/07	0.0312	0.0241	0.0000	0.0018	0.0021	0.0163	0.0038
DT-1	2/8/07-3/7/07	0.0306	0.0220	0.0000	0.0031	0.0038	0.0137	0.0014
DT-1	3/7/07-4/4/07	0.0463	0.0310	0.0000	0.0023	0.0080	0.0123	0.0084
DT-1	4/4/07-5/2/07	0.0732	0.0537	0.0000	0.0042	0.0036	0.0278	0.0181
DT-1	5/2/07-5/31/07	0.0216	0.0179	0.0000	0.0034	0.0015	0.0107	0.0022
DT-1	5/31/07-9/12/07	0.0829	0.0647	0.0000	0.0032	0.0057	0.0439	0.0120
DT-2	2/3/06-2/24/06	0.1473	0.1377	0.0025	0.0028	0.0084	0.1021	0.0245
DT-2	2/24/06-3/16/06	0.1028	0.0872	0.0000	0.0053	0.0046	0.0496	0.0277
DT-2	3/16/06-4/6/06	0.0689	0.0587	0.0000	0.0041	0.0058	0.0365	0.0123
DT-2	4/6/06-4/27/06	0.1043	0.0843	0.0011	0.0030	0.0068	0.0569	0.0175
DT-2	4/27/06-8/4/06	0.1858	0.1611	0.0000	0.0001	0.0122	0.1213	0.0274
DT-2	8/4/06-2/8/07	0.0253	0.0201	0.0000	0.0019	0.0026	0.0132	0.0024
DT-2	2/8/07-3/7/07	0.0786	0.0786	0.0000	0.0044	0.0170	0.0493	0.0079
DT-2	3/7/07-4/4/07	0.0756	0.0365	0.0000	0.0040	0.0062	0.0169	0.0093
DT-2	4/4/07-5/2/07	0.0526	0.0386	0.0000	0.0046	0.0023	0.0195	0.0122
DT-2	5/2/07-5/31/07	0.0559	0.0464	0.0000	0.0038	0.0057	0.0305	0.0064
DT-2	5/31/07-9/12/07	0.1140	0.0723	0.0000	0.0081	0.0066	0.0466	0.0109

¹ Dust + organics includes organic fraction of dust; all other rates calculated on an organic-free basis.