POTENTIAL HEALTH HAZARDS OF OWENS LAKE DUST?

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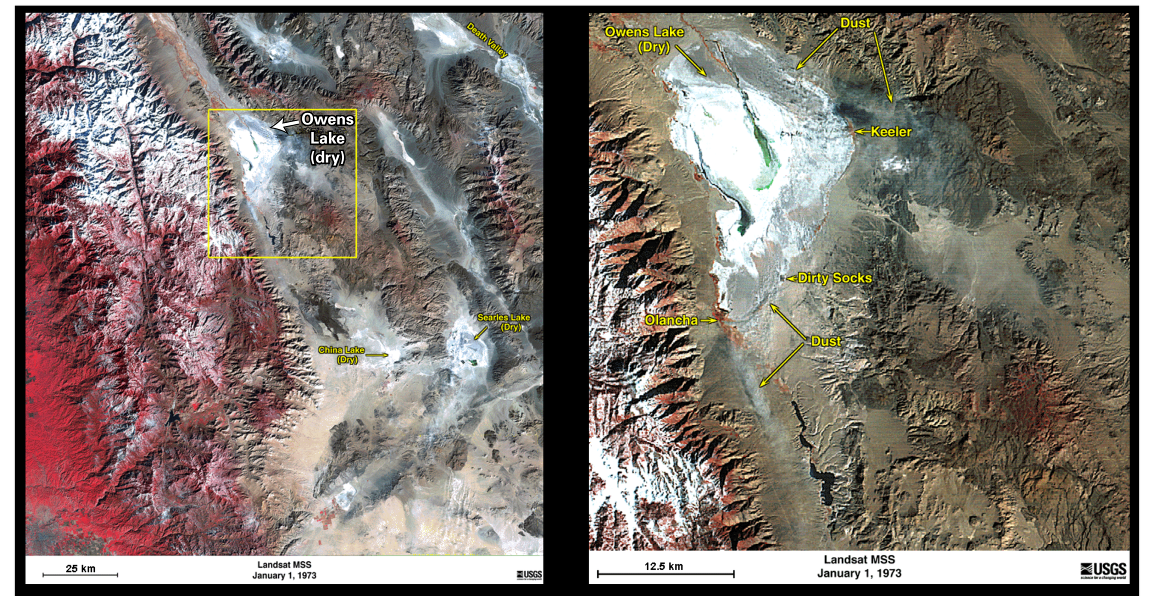

Owens Valley, on the eastern side of the Sierra Nevada, is drained by the Owens River. During most of the Pleistocene, the Owens River terminated in Owens Lake, which overflowed southward during wetter periods. Owens Lake was artificially desiccated when its feeder streams were diverted in the early 1900's by the City of Los Angeles; the dry lakebed became the single largest dust source in North America (by some estimates 7% of the total PM-10 dust in the U.S.). Note dust plumes (labeled) streaming off the lakebed.

ABSTRACT

Mineral dusts from the desiccated playa of Owens Lake, California, contain elevated concentrations of many metals known to have toxic effects on animals and plants. To assess the possible hazards and element sources, we are (1) analyzing trace-element contents of the fine-grained minerals and the soluble fractions of deposited dust, playa sediment, and aerosol samples collected during dust storms, and (2) using SEM microbeam and microprobe techniques.

Potentially toxic elements in the <50-µm fraction of deposited dust include (concentrations in ppm): As (10-50), Cr (17-56), Cu (22), Mo (0.5-3), Ni (16), Pb (50-400), Sb (6-14), Th (10-16), and U (3-8). Enhanced mobility in alkaline conditions (pH of dust and playa samples is 9-10) is indicated by high concentrations of several elements in water extracts (20:1 by weight, pH 5, 5-minute shake) of dust samples—As, Mo, and U values are as high as 2700, 650, and 170 µg/L, respectively. Dusts and aerosols are strongly enriched in sulfate from sodium sulfate in playa sediment: elemental S concentrations in saline dust events can be as much as 10 %. The health and ecological effects of soluble alkaline sulfate aerosols are poorly known but of potential concern.

Dust-deposition rates of some metals and sulfates in Owens Valley equal or exceed estimates for industrialized areas of the world. Much Owens Lake dust is <10 µm in diameter, and SEM studies reveal extremely fine (submicron) particles. Given composition, size, and deposition rates (1991-1998 average of 150 $g/m^2/yr$ of fine dust at one site), a large fraction of these metals could be transported hundreds of kilometers and easily respired. Terminal lake basins such as Owens Valley could be globally important sources of metal-bearing dusts.

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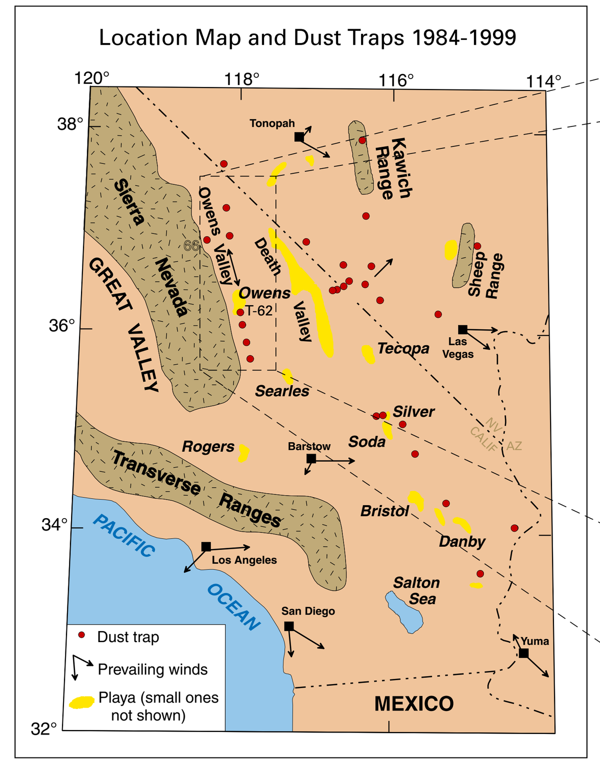
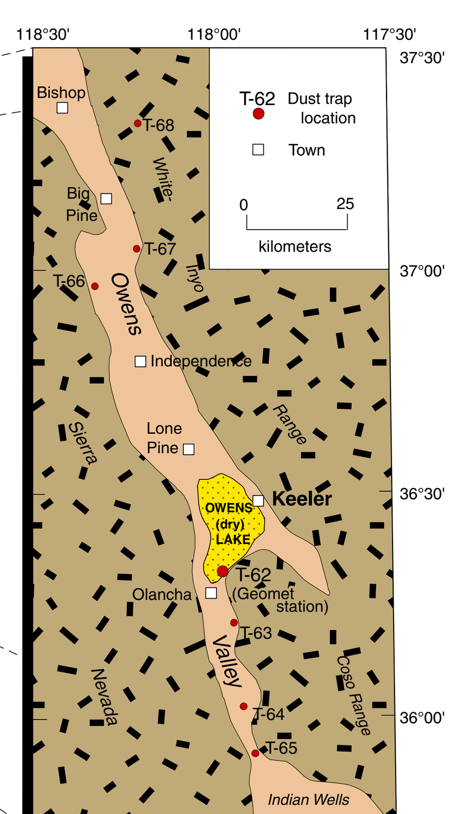
METHODS

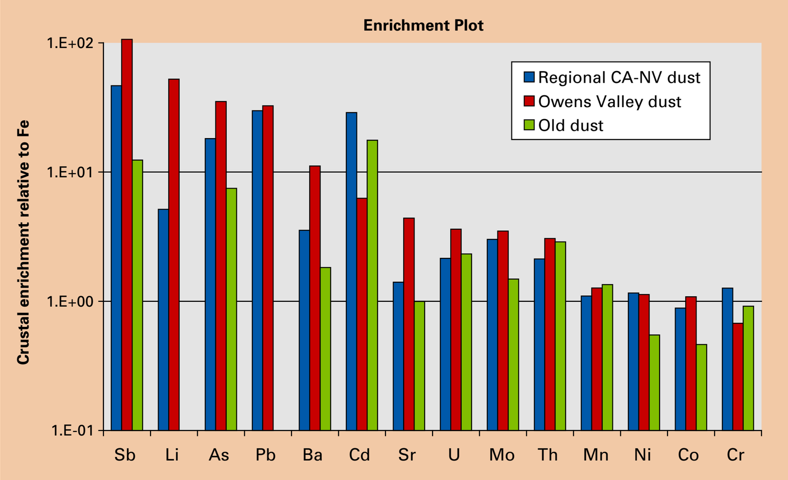
The dust traps consist of a Teflon- or enamel-coated angel-food cake pan mounted on a steel post about 2 m above the ground. This height nearly eliminates trapping of coarse grains traveling by saltation. Glass marbles fill the upper part of the pan above a supporting piece of 0.25-inch-mesh metal screen that rests 3-4 cm below the rim. Thus, the dust samples represent both wet and dry deposition. Samples are retrieved by washing the trap components with distilled water into plastic 1-L bottles.

Samples characterized as "old" dust were collected from fine-grained deposits in natural cavities (vugs) formed by weathering in the rhyolite tuffs along the crest of Yucca Mountain. These vugs are isolated from deposition by alluvial or slope processes; thus, the calcareous, silty sediment within the vugs must have been deposited by eolian processes over as much as several thousand years. These samples permit comparison of modern dust to "old" dust that accumulated largely before settlement and industrial development.

Analytical techniques used on the <50 µm fraction of dust samples included INAA, ICP-AES, and ICP-MS. These three techniques yield results for different, but overlapping, suites of elements and provide results with different levels of precision. Dust samples from near Owens (dry) Lake were incrementally sampled and leached at a 20:1 ratio. That is, 2.5 g dust in 50 ml leachate. The leachate is designed to simulate meteoric water for soil samples west of the Mississippi. The leachate was slightly acidified (pH 5) DI water. Sample and leachate were combined and the sample was hand shaken for five minutes, allowed to settle and filtered with a 0.45-micron syringe filter. The filtrate was then preserved by addition of a small volume of Ultrex Nitric acid and submitted for ICP analysis. Complete details of this leach procedure can be found in a paper by Hageman and Briggs (2000).

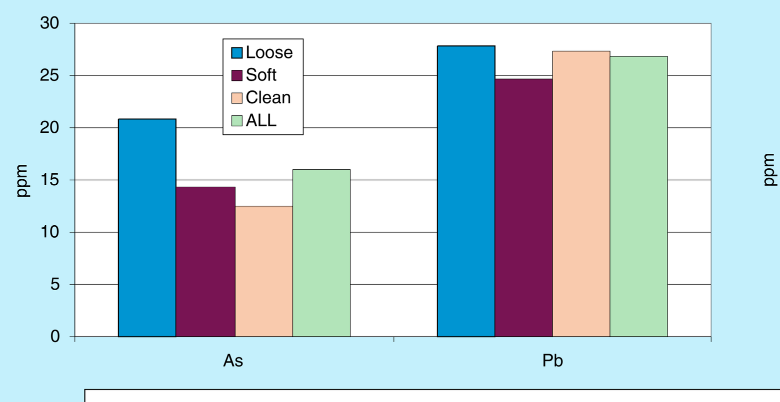


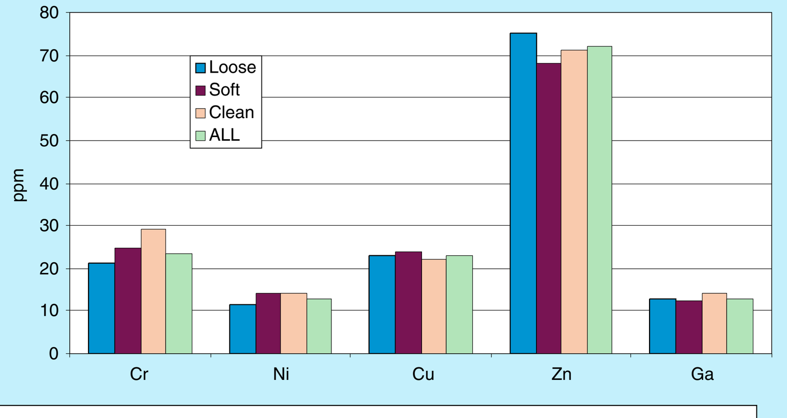




Average crustal enrichment relative to Fe of selected elements in dust samples, sorted by relative enrichment in Owens Valley dust (see map for dust trap locations). Regional CA-NV dust (average of all sites not in Owens Valley) and Owens Valley dust are similarly enriched in many trace elements, including Pb, U, Mo, Th, Mn, Ni, and Co. However, Owens Valley dust is distinctively enriched in Sb, Li, As, Ba, and Sr relative to regional dust and to "old dust". These elements in Owens Lake dust are derived by concentration of evaporated lake water and shallow ground water (Li, As, Sr) as well as from sediment from the Sierra Nevada (Ba) and tailings from mines in the Inyo Range (As and Sb).

Potentially Toxic Elements in Surface Crust at Site T-62

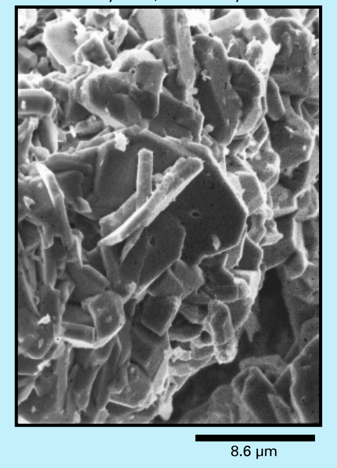




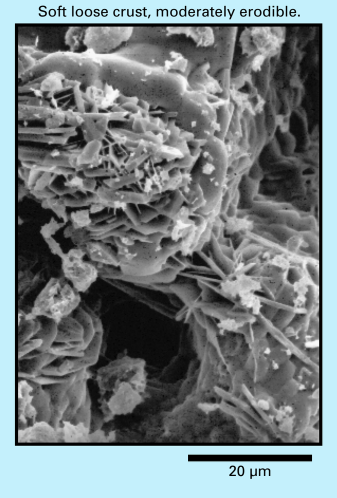
Analyses of the composition of surface crusts at site T62 (see map) were conducted using PIXE at Texas Tech University (note scale change). The plots show some variation in trace-metal content with the type of crust analyzed. Arsenic, in particular, seems to be associated with the most salt-rich crusts.

Loose -- White, salty-appearing, little or no crust, most susceptible to wind erosion.
Soft -- Loose, broken crust, with loose sediments present atop crust, moderately susceptible to wind erosion.
Clean -- Clean, harder crust, without loose particles present, least susceptible to wind erosion.

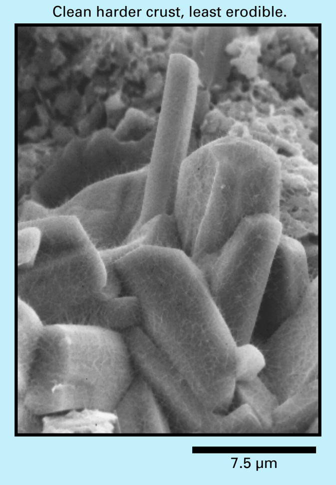
Loose salty crust, most easily eroded.



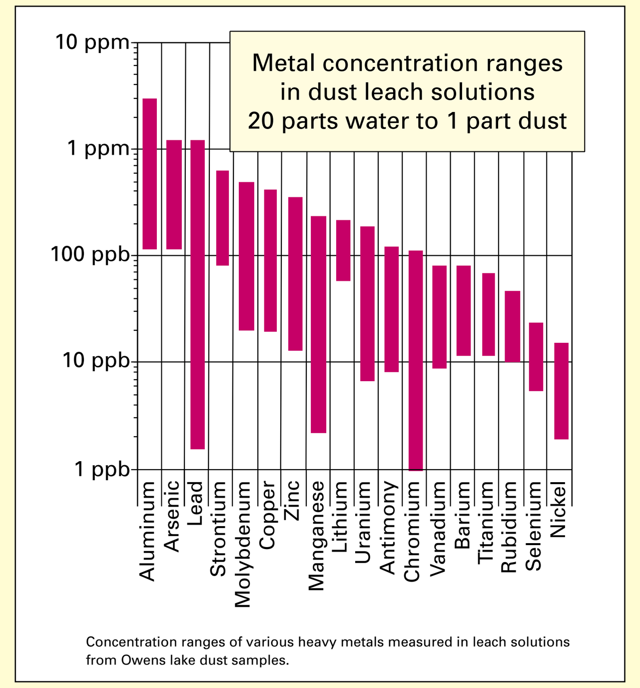
Soft loose crust, moderately erodible.



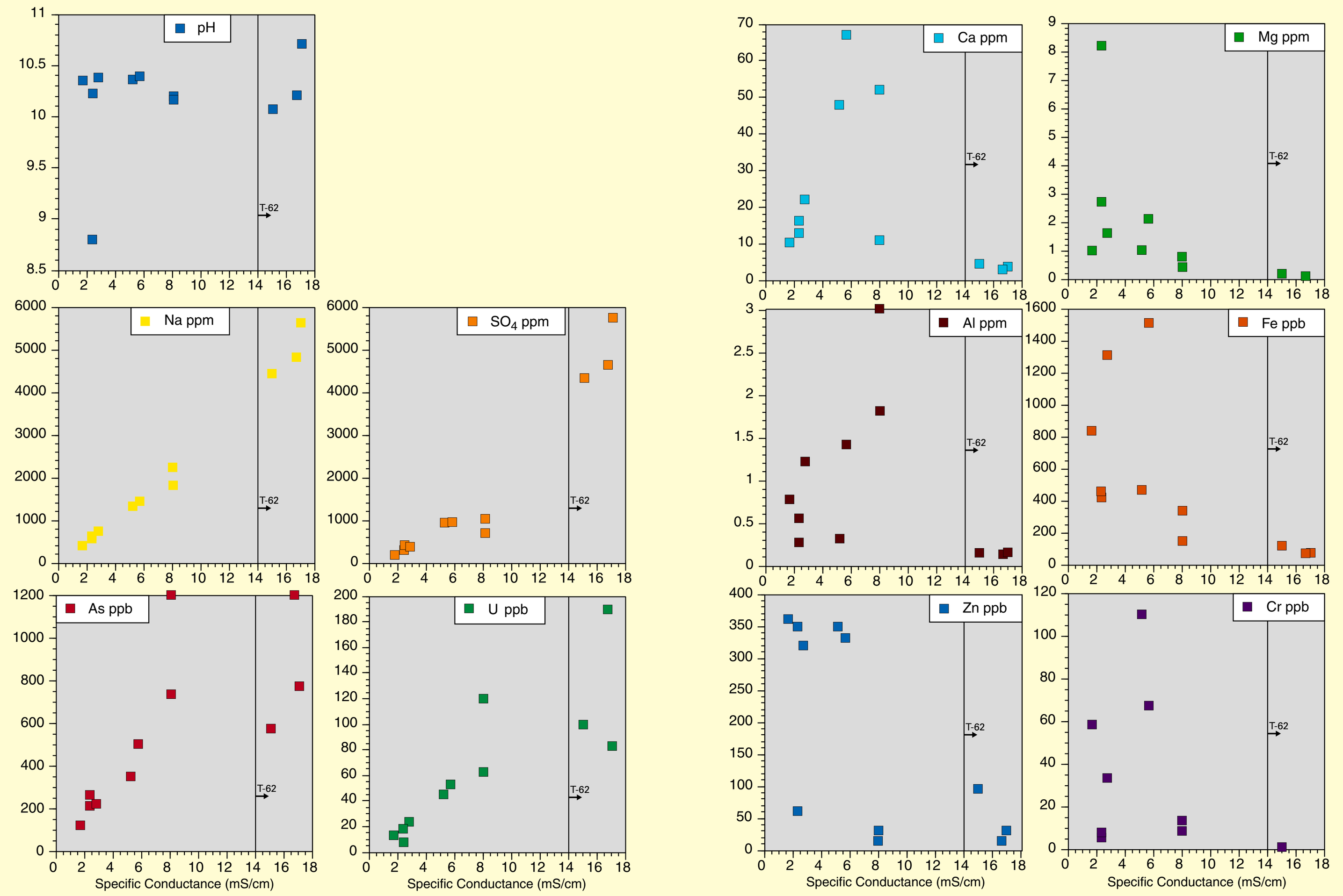
Clean harder crust, least erodible.



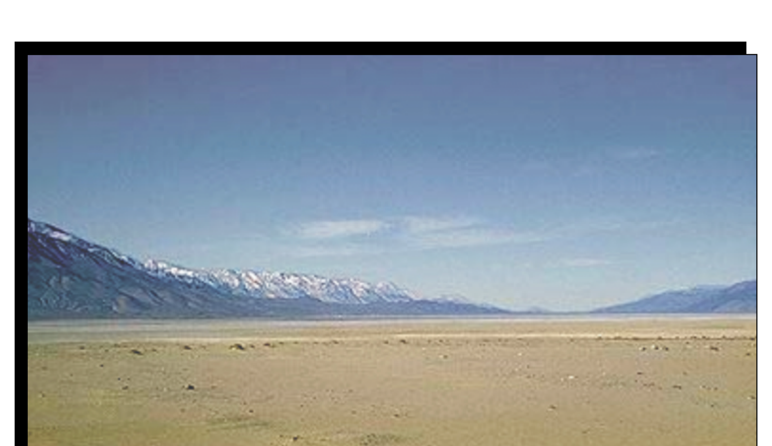
Leach Tests on Dusts from T-62 and Keeler



Concentration ranges of various heavy metals measured in leach solutions from Owens lake dust samples.

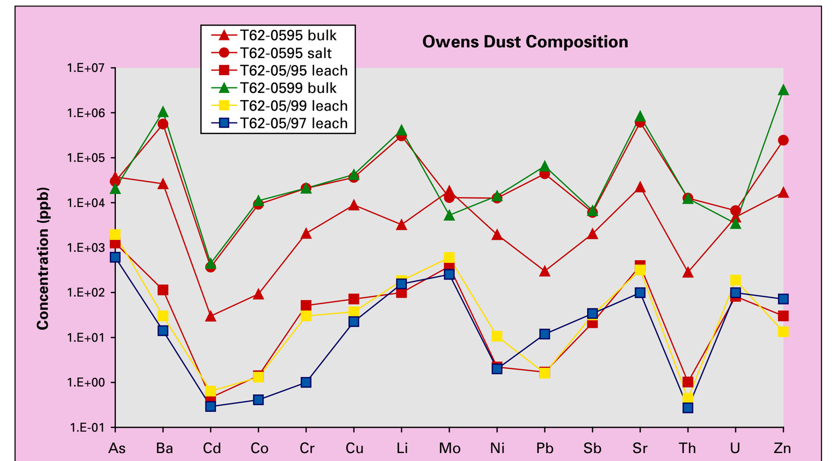


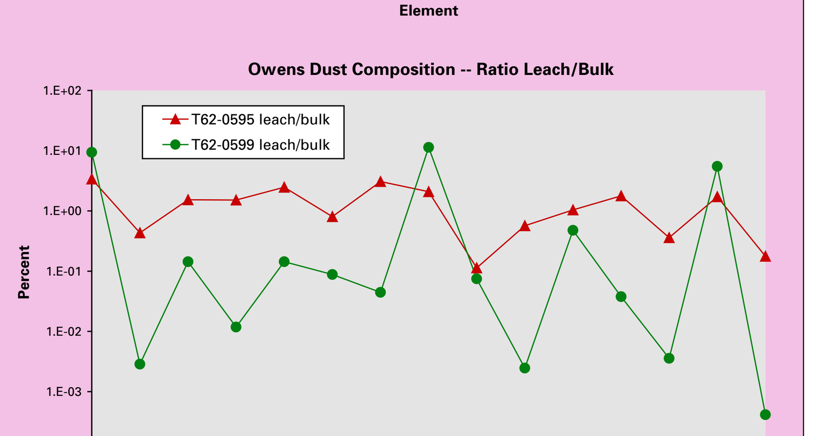
General linear correlations between specific conductance and concentrations of sodium and sulfate, as well as trace metals such as arsenic, uranium, and selenium, indicate that dissolution of halite and sodium sulfate salts (possibly containing the trace elements in solid solution) may be an important control on leachate composition. However, non-linear variations relative to specific conductance in the concentrations of other cations and heavy metals (such as Ca, Fe, Cr, Zn, and Pb) may indicate that other evaporative minerals such as carbonates also influence leachate compositions. Note: Samples with conductances >14 mS/cm are from dust trap T-62; all other samples are Keeler building dust.



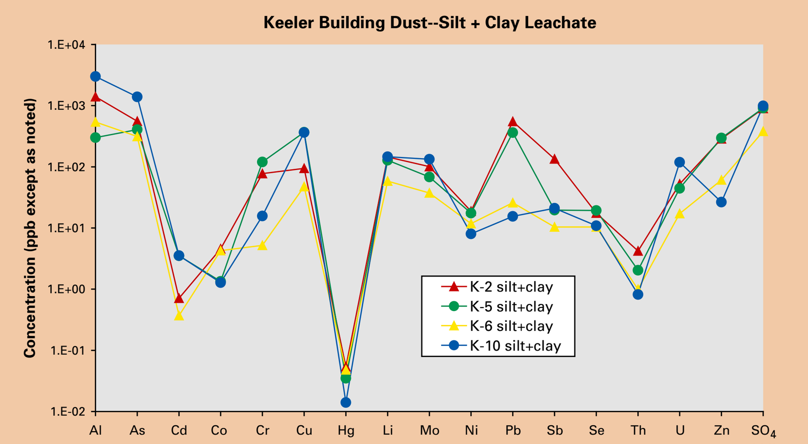
Powerful winds are funneled through Owens Valley between the Sierra Nevada on the west and the White-Inyo Range on the east. Though dust storms can arise at any time during the year, strong northerly winds and a fluffy salt crust on the lakebed combine to produce the largest storms during winter and early spring. These plumes have been tracked visually at least 250 km to the south, and the chemical signature of dust from southern Owens Valley is recognizable in deposited dust as much as 400 km to the east. From top to bottom, these photos show (1) a clear day on Owens (dry) Lake, looking north; (2) a small dust storm (view west to Sierra Nevada); (3) a large dust storm blowing south from Owens Lake.

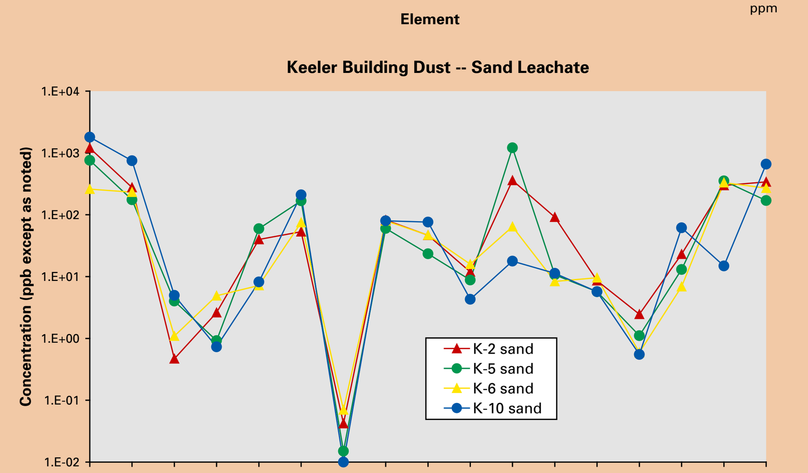
Photo by W. Cox, Great Basin Unified Air Pollution Control District



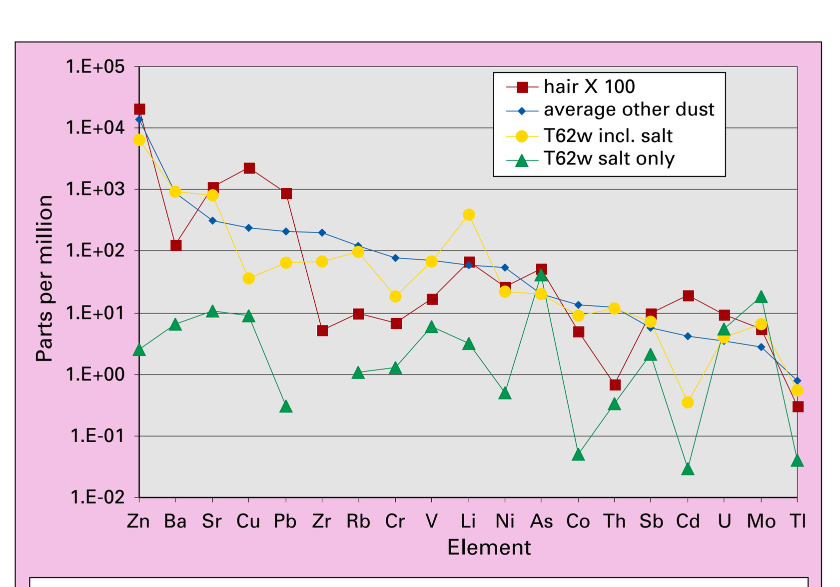


Samples of the <50 µm fraction of modern dust from the south end of Owens Lake (T62; see map for location of dust trap) show relatively high concentrations of many potentially toxic metals. Leachates of the same samples also contain significant amounts of these metals due to their mobility at high pH (9-10 in the solutions). Leachate contents of As, Cr, Li, Mo, Sb, and U are particularly high relative to their contents in the bulk <50 µm fractions.

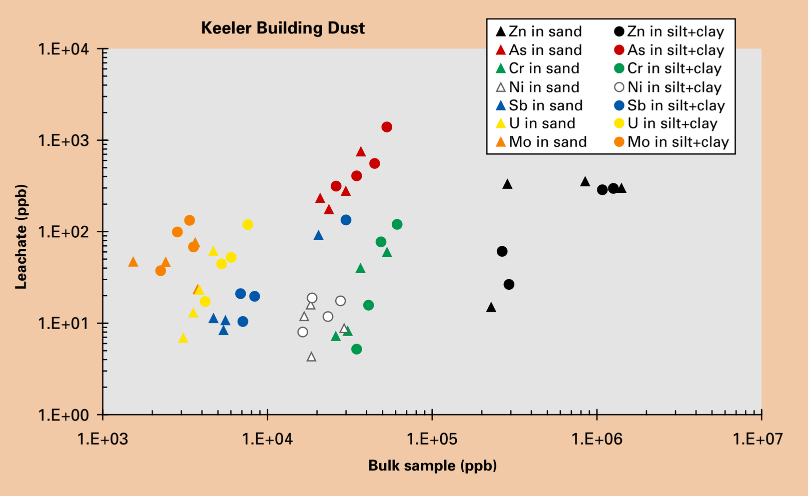




Samples of dust collected from abandoned buildings in the town of Keeler (see map for town location) produce leachates that are similar in composition to the dust collected in trap T62 on the south end of Owens Lake. Among the Keeler samples, some differences occur in contents of certain elements, especially Cr, Pb, Sb, and Zn.



Contents of some metals in a single sample of hair from a resident of southern Owens Valley show a striking resemblance to contents of modern dust collected at site T62. Average contents of dust samples from other sites in southern California and Nevada (see location map) shown for reference.



Some elements such as As, Cr, Sb, and U, appear to increase in the leachate proportional to an increase in the bulk sample. Other elements such as Mo, Ni, and Zn do not show this relationship. These differences may be due to the relative mobility of these metals at high pH. Note that As is the most concentrated of the metals in the leachate fractions.

Comparison of element deposition (flux) and emission rates (g/ha/yr)

Element	Owens Reheis et al. (in press)	Regional Reheis et al. (in press)	Remote[a]	Rural[a]	Urban[a]	Los Angeles[b] (emissions)	Global volcanic[c] (emissions)
As	1.8-42	0.39-3.6	0.31	10-20	25-60	2-3	(0.0027)[d]
Cd	0.044-1.1	0.0082-1.2	0.0023-0.050	1.2-8.8	7.0-260	*N.R.*	0.0053
Cr	2.8-71	1.6-17	3.0	10-360	10,600	25-30	*N.R.*
Cu	52-370	5-90	0.012-1.9	18-230	160-600	*N.R.*	0.020
Mn	59-800	18-160	6.2	21-250	<1,000	*N.R.*	*N.R.*
Mo	0.25-3.6	0.096-0.67	*N.R.*	<10	*N.R.*	*N.R.*	*N.R.*
Ni	2.9-65	1.0-13	*N.R.*	10-<230	100-<2,240	8-12	*N.R.*
Pb	32-500	2.5-75	0.012-9.3	19-320	100-12,360	90-95	0.0168
Sb	0.56-24	0.12-1.1	0.16	<10	*N.R.*	*N.R.*	(0.0001)
V	7.0-110	2.6-22	*N.R.*	36-12,400	43-8,300	*N.R.*	*N.R.*

[*N.R.*, not reported]
[a] Sources in Galloway et al. (1982; bulk samples only)
[b] Estimated from Table 4.2 in South Coast Air Quality Management District (2000)
[c] Calculated from data in Table 3 of Hinkley et al. (1999)
[d] Values in parentheses from Kilauea only (data of Hinkley et al., 1999)

Conclusions

The results of the chemical leach tests on dust samples from Owens Lake and Keeler show that the dusts are alkaline and contain a wide variety of relatively soluble heavy metals and metalloids, such as aluminum, arsenic, uranium, chromium, molybdenum, copper, and zinc. It is possible that the dusts, when reacted with rain waters or when inhaled by humans or other organisms, yield a potential environmental source of these metals in quite bioavailable forms. At present, it is difficult to determine whether these soluble metals are present in the dusts in sufficient concentrations to pose short-term or long-term environmental health hazards. Further work is clearly indicated, for example, to determine if rain or snowmelt waters that have come into contact with appreciable amounts of the dusts contain sufficiently high concentrations of these metals to be of concern to humans or other organisms that drink such waters. Further work is also indicated to determine if the dusts pose a potential health threat when inhaled or indirectly ingested by humans or other organisms. Such work might include, for example, testing of local residents during the high-dust season (late winter-early spring) to determine if dust exposure results in elevated concentrations of these metals in the blood, urine, hair, or other parameters commonly measured to assess heavy metal exposure.

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