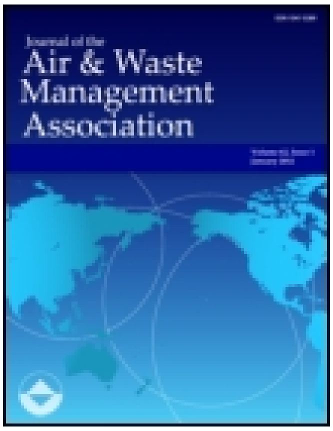

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Aerosols present upwind and downwind of freeways in the Los Angeles Basin were collected in five particle size ranges by Lundgren impactors with after filters and analyzed for elemental content by ion-excited x-ray emission. The contribution of freeway traffic to total airborne particulate load was obtained by subtracting the local background, measured by an upwind sampler, from the values obtained by downwind samplers on a size by size, element by element basis. This contribution correlated reasonably well with estimates derived from automotive and roadbed expendable rates. Traffic-derived aerosols, normalized to vehicular flow, were considerably lower in mass downwind of depressed roadbed configurations than either at grade or raised configurations. A line source model, combined with literature values for emitted lead, produced good agreement with results obtained in the at grade configuration.

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The contributions of traffic to particulate matter in near roadway locations assume considerable importance in situations involving large numbers of vehicles. In order to examine this problem, the California Air Resources Board initiated a study through the University of California, Davis, of particulate matter in near roadway areas.[1] The two main thrusts involved the correlation of particulate matter with automotive and roadbed expendables, and the examination of particulate dispersal patterns as a function of weather, traffic and roadbed configurations.

Particulate matter was collected using up to 6 Lundgren rotary drum impactors with after filters.* Particles were separated into effective diameters ($\rho = 1$) of $\sim$100 to 17 μm, 17 to 5 μm, 5 to 2 μm, 2 to 0.6 μm, and 0.6 to 0.1 μm, and collected respectively on 4 paraffin-coated mylar strips, and a Whatman 41 after filter. Collection efficiency was verified by comparisons with Hi-volume and filter sampling, while particle sizing was established by uranine dye studies, studies of bounce off versus paraffin coating, and scanning electron microscope pictures of the first four stages. Losses of particles below 17 μm were established as being less than 15%.

* Purchased from Environmental Research Corporation, St. Paul, MN.

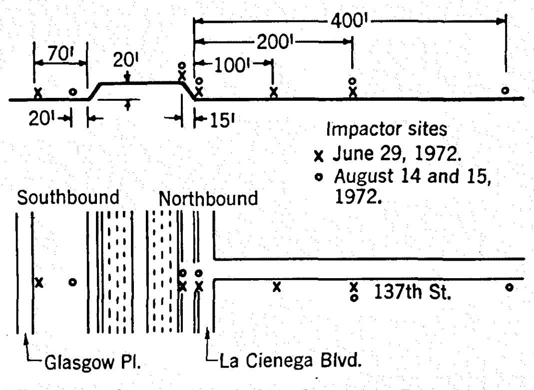

Figure 1. Site number 4 (SD). San Diego Freeway near 137th Street. 6/29/72 and 8/14–15/72.

Samplers were placed in arrays at locations along the instrumented "42 mi freeway loop" in the Los Angeles basin, generally at sites selected by the California Division of Highways in its ongoing study of freeways. Sites were selected to illustrate major roadbed configurations and alignments with prevailing summer winds. The sites, configurations, and approximate wind alignments were as follows: Site 1, Santa Monica Freeway at 4th Street, a 10 meter cut section with parallel winds; Site 2, Harbor Freeway at 146th Street, a 10 m cut section with transverse winds; Site 3, San Diego Freeway near the Harbor Freeway intersection, an at grade freeway with transverse winds; Site 4, (Figure 1) San Diego Freeway at 137th Street, a 5 m fill section freeway with transverse winds. Neighborhoods were residential with largely single family residences, including mature trees, for Sites 1, 2, and 4, while Site 3 was mostly an open field. Samplers were located 1 m above the ground, as far from obstructions as possible, and faced into the prevailing wind. This orientation, checked every 30 min, provided quasi-isokinetic sampling at wind velocities between 1 and 2 m/sec. Samplers were located upwind of the freeway and at locations downwind from close to the roadbed to ~160 m from the median strip. Sampling took place during nine 24 hr days between March and August, 1972; Site 1, 3/22 → 3/24 and 6/27; Site 2, 6/28; Site 3, 8/16 → 8/17; Site 4, 6/29 and 8/14 → 8/15. Weather data were obtained from local sources, the Division of Highways on freeway stations, and hand held velocity and direction instrumentation. Traffic flow and velocity data were supplied by the Division of Highways, while traffic mix (and occasional flow) counts were made by staff personnel. Traffic flows of up to 17,000 vehicles/hr were encountered, while daily averages of 200,000 to 250,000 vehicles were common. Truck traffic was a small percentage at almost all times.

All samples were processed at Davis by being separated into 2 hr segments and analyzed for all elements heavier than sodium by ion-excited x-ray analysis (IXA).[2–5] Detectable limits for the stages were around 10 nanograms/m^3 of air for most elements, but cadmium region elements and rare earths were much worse, ranging in the hundreds of nanograms/m^3 of air, as were results from the filters. Due to the choice of filter material (Whatman 41) and analytical technique (x-rays), elements lighter than potassium were not available from the after filters. About 6000 analyses were made during this program, including some x-ray fluorescence and ESCA measurements, the latter done at the Lawrence Berkeley Laboratory (T. Novakov). Accuracy of the method was established through use of 36 gravimetrically measured elemental standards. It was verified by 8 interlaboratory and intermethod comparisons, including 10 hi-vol samples taken on fiberglass at Site 3 during our sampling regime and analyzed for lead by atomic absorption in the Division of Highways' laboratories and by IXA at Davis.[1]

The contribution of traffic to particulate matter was obtained by subtracting upwind values from downwind values, element by element, size by size, during each 2 hr period when upwind and downwind had a clear meaning, or when calm periods enormously enhanced the traffic's dominance over the relatively low background values at the sites near the ocean (3 and 4) (Table I).

Particulate matter seen near the roadways correlated reasonably well with elemental content and use rates of expendables associated with traffic (fuel, tires, roadbed wear, and exhaust train erosion providing most of the particulate mass).[6] Some fine sulfur particulates were seen in association with traffic, which were tentatively identified as originating in gasoline, or, possibly motor oil combustion. The most unambiguous traffic tracer proved to be, as expected, lead in correlation with bromine, mostly in the <5 μm size range. The Br/Pb ratio was 0.33 ± 0.03, close to the value for PbBrCl of 0.355.

The second part of the program, involving an investigation of dispersal patterns from highways, was accomplished by examining the levels of lead and bromine downwind of highway sections. Several 2 hr periods were identified during which the wind had a mean velocity greater than 1 m/sec and was aligned either transverse to or parallel to the highway alignment within ±45°. Lead and bromine values from locations up to 160 m from the highway median were collected, normalized to traffic flow, and separated into two size ranges, < 5 μm or >5 μm. An example of one of the 2 hr plots is shown in Figure 2. Upwind values were then subtracted, and all data collected within a given 2 day sampling period that met the meteorological conditions were averaged together. These data are displayed in Table II for the size fraction below 5 μm. While error flags are not included in the table, analyses of variability within a given sampling period for each 2 hr increment indicate a standard error of about ±20% in the result.

Table I. Relative elemental composition of freeway associated particulates.

	$D_\rho < 5\mu m$ (80%)	$D_\rho > 5\mu m$ (20%)	Weighted average
Al	N.A.	0.29	N.A.
Si	N.A.	1.32	N.A.
P	N.A.	<0.006	N.A.
S	N.A.	<0.016	N.A.
Cl	N.A.	0.11	N.A.
K	0.004	0.019	0.007
Ca	0.03	0.48	0.12
Fe	0.05	0.76	0.19
Cu	0.003	0.014	0.005
Zn	0.013	0.08	0.024
Br	0.33	0.19	0.30
Pb	≡1.000	≡1.000	≡1.00

N.A.—No quantitative data available due to the choice of filter substrate. Observed amounts of these elements were in all cases minor.

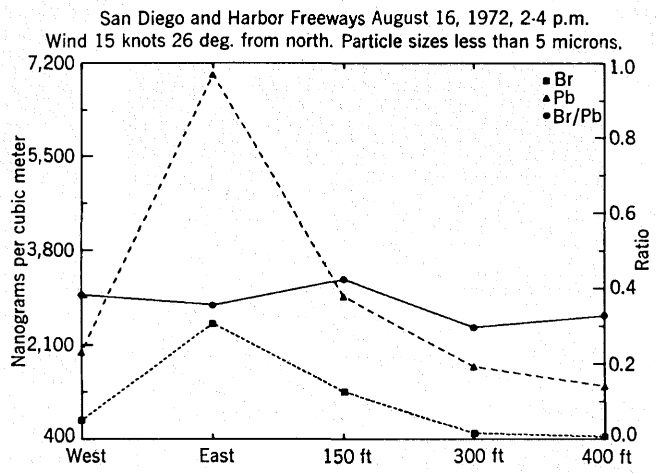

Figure 2. An example of one of the 2 hr plots used to prepare average values of dispersion from various roadbed configurations. This case was for site 3, 8/16/72, 1400–1600 hr, with a mean wind value of 7 m/sec from a direction 26° west of north, for particle sizes less than 5 μm. Lead and bromine values are given in nanograms/m^3 of air, and the Br/Pb ratio is exhibited on the right hand scale. Distances are in feet from the edge of the roadbed (1 ft = 0.3 m). The mean Br/Pb ratio for this period was 0.36.

Also included in Table II is a calculation of the results expected at the at grade site (3) using literature values of total emitted lead,[7,8] arbitrarily separated into greater than 5 μm (20%) and less than 5 μm (80%) size fractions using the ratio seen in this study. A linear source mixing cell with a height 3.5*m and a width 60 m was used to establish on roadway levels, transposed laterally by the average wind velocity of about 3 m/sec. A line source diffusion model[9,10] using an estimated Pasquill stability factor of C was used to predict subsequent dispersion operating from an equivalent line source location about 4 m upwind of the downwind roadway edge. The agreement at the roadway edge is thus fortuitous since no parameters were free to vary from best estimates. However, under these conditions, the agreement between the results of literature estimates arising from laboratory studies and the results of the field tests is encouraging in that it appears to confirm ready calculation of dispersal mechanisms in simple cases.

In conclusion, dramatic effects of roadbed configuration are evident in Table II, although interpretation is confused by the well established roadway plantings characteristic of sites 1 and 2. The similarity between site 1, with wind parallel, and site 2, with wind transverse, can possibly be explained by the variability in horizontal direction of the generally cool, vigorous ocean breezes. The relatively high downwind values at site 4, a fill section, could be qualitatively reproduced by dispersion from a raised source. These calculations also have shown extreme sensitivity to the estimated stability class for this configuration, which might explain the variations between the June and August sampling periods.

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* The 3.5 m height was chosen as the effective height of the mixing cell at twice the height of the automobile dominated traffic.

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Table II. Traffic-derived lead levels versus sampling site. Lead levels are in ng/m^3 of air for particles less than 5 μm in effective aerodynamic diameter normalized to total vehicle flow of 5000 vehicles/hr. Winds are greater than 1 m/sec, with mean values of about 3 m/sec. Variance as derived from spread in values, ±20%.

Site, Date	Wind	Distance from Highway Median (Meters)			
		27m	40m	100m	160m
Site no. 1, 6/72 (Cut Section)	Parallel	4.9	0.85	0.30	—
Site no. 2, 6/72 (Cut Section)	Transverse	4.5	1.7	0.26	—
Site no. 3, 8/72 (At grade)	Transverse	4.0	3.1	1.40	0.35
Site no. 3 (calculated) (At grade)	Transverse	4.0	3.4	1.40	0.41
Site no. 4, 6/72 (Fill Section)	Transverse	6.0	2.7	2.2	—
Site no. 4, 8/72 (Fill Section)	Transverse	3.6	2.0	4.0	3.5
Site no. 4 (average)	Transverse	4.8	2.3	3.1	—