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PM₁₀ Source Apportionment Study in Pleasant Valley, Nevada

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ABSTRACT

A source apportionment study was conducted between March 18 and April 4, 1988, at Pleasant Valley, Nevada, to evaluate air pollutant concentrations to which community residents were exposed and the source contributions to those pollutants. Daily PM₁₀ samples were taken for chemical speciation of 40 trace elements, ions, and organic and elemental carbon. Hourly hydrogen sulfide, wind speed and direction, sigma theta, temperature, and relative humidity data were also collected. The objectives of this case study are: (1) to determine the emissions source composition of the potential upwind source, a geothermal plant; (2) to measure the ambient particulate concentration and its chemical characteristics in Pleasant Valley; and (3) to estimate the contributions of different emissions sources to PM₁₀.

Source emissions from the power-plant cooling-tower and geological material around the source and receptor sites were sampled and chemically analyzed. Chemical mass balance receptor modeling was performed to determine the contribution of the power-plant plume and other sources in the area to PM₁₀ concentrations. The study found that: (1) particulate emissions from the geothermal cooling-tower plume consisted primarily of sulfate, ammonia, chloride, and trace elements; (2) no significant quantities of toxic inorganic species were found in the ambient air; (3) ambient PM₁₀ concentrations in Pleasant Valley were within Federal standards; and (4) source contributions to PM₁₀ were approximately 60% geological material; 20% motor vehicle exhaust; and 10% cooling-tower plume. The PM₁₀ levels, the chemical concentrations, and the sum source contribution estimates are much lower than those levels found to be deleterious to public health.

INTRODUCTION

Pleasant Valley is a small residential community (population of approximately 600) located between Reno and Carson City, the two major urban centers in northern Nevada. A 12.5-megawatt geothermal power plant operated by Caithness Power, Inc., is located in Pleasant Valley approximately 20 km south of Reno. This power plant converts

450 °C groundwater in the Steamboat geothermal field into energy which supplies power to 12,500 households in northern Nevada.

Residents in Pleasant Valley have reported the detection of odors in the neighborhood since the beginning of 1988. These residents have expressed concern about potential adverse health effects which might be caused by gases and particles which accompany the odors. With the assistance of Washoe County District Health Department officials, an ambient and source monitoring program was conducted between March 18 and April 4, 1988. The study was designed to evaluate air pollution concentration levels to which the community residents were exposed.

This paper addresses the particulate phase of the study. Its objectives are: 1) to determine the chemical constituents of emissions from the geothermal power plant; 2) to measure the ambient concentrations of particulate chemical species in Pleasant Valley; and 3) to estimate the contributions of different emissions sources to suspended particulate matter in the respirable size fraction (PM₁₀, particles less than 10 μm in aerodynamic diameter). In order to attain these objectives, filter samples of suspended particulate matter were taken both in the cooling-tower plume and on the ground. The filter deposits were characterized for a number of chemical species. The measurements in the plume form a chemical fingerprint which can be distinguished from the fingerprints of other particulate contributors such as geological material, motor vehicle exhaust, and wood burning. The Chemical Mass Balance (CMB) receptor model (Watson et al., 1990) was applied to these data to determine the contribution of the power-plant plume and other sources to the inhalable particulate concentrations measured by the ground-based sampler. Receptor models are widely used in the development of State Implementation Plans for meeting ambient air quality standards (Watson et al., 1989).

SAMPLING, ANALYSIS, AND MODELING

PM₁₀ (particulate matter with aerodynamic diameter less than 10 microns) samples were taken daily at 20540 Eaton Road, Pleasant Valley, NV, for 24 hours per day from March 18 to April 4, 1988.

Table 1
Pleasant Valley Source Apportionment Study
Ambient Measurements^a

<u>Measurement</u>	<u>Sampling Period</u>	<u>Measurement Method/Instrument</u>
PM ₁₀	Daily, 24 Hours/Day	DRI MEDIUM-VOLUME (PM ₁₀) Sampler
PM ₁₀ Mass	Daily, 24 Hours/Day	Gravimetric Analysis on Teflon-Membrane Filters with Cahn 31 Electro-Microbalance
PM ₁₀ Elements (from Al to Pb)	Daily, 24 Hours/Day	X-ray Fluorescence Analysis on Central Portion of Teflon-Membrane Filters with Kevex 700/800 XRF Analyzer
PM ₁₀ Chloride, Nitrate, and Sulfate Ions	Daily, 24 Hours/Day	Ion Chromatographic Analysis on $\frac{1}{2}$ Quartz-Fiber Filter Extracts with Dionex 4000i Ion Chromatograph
PM ₁₀ Ammonium Ion	Daily, 24 Hours/Day	Automated Colorimetric Analysis on $\frac{1}{2}$ Quartz-Fiber Filter Extracts with TRAACS 800 Technicon System
PM ₁₀ Organic and Elemental Carbon	Daily, 24 Hours/Day	Thermal/Optical Reflectance Carbon Analysis on 0.5 cm ² Punches from Pre-fired Quartz-Fiber Filters with DRI/OGC Thermal/Optical Carbon Analyzer

Samples were taken on filters with a DRI MEDIUM-VOLUME PM₁₀ (DRI-10) sampler. The DRI-10 is a special sampler designed to collect PM₁₀ samples onto Teflon-membrane and pre-fired quartz-fiber filters at a flow rate of 30 liters per minute.

In addition to the PM₁₀ measurements, a Meloy Model 285 hydrogen sulfide analyzer and meteorological monitors were installed at the sampling site to continuously monitor hydrogen sulfide (H₂S), wind speed, wind direction, sigma theta, temperature, and relative humidity. These continuous measurements were averaged over six-minute and one-hour intervals.

Table 1 summarizes the ambient measurements. Chow (1987) describes the analysis methods which were applied in this study. Source samples for soil, paved-road dust, storage piles, and geothermal cooling-tower plumes were also collected in both PM₁₀ and PM_{2.5} (particulate matter with aerodynamic diameter less than 2.5 microns) size fractions.

Geological samples were taken from vacant areas and storage piles in the vicinity of the sampling site and geothermal plant. Samples were also swept from roadways to represent

resuspended road dust. These samples were dried, sieved, and resuspended into a stilling chamber using a forced air jet. PM₁₀ and PM_{2.5} samplers were placed in the chamber and the resuspended dust was sampled just as it would be at a receptor site. The filter deposits were then submitted to the same chemical analyses performed on receptor samples. Cooling-tower plume samples were collected using a suspended platform to locate the sampler in the plume to sample cooling-tower emissions. Concurrent upwind background samples were also taken to allow the subtraction of particles from the ambient air which were entrained in the plume. The background sample was taken over a longer period than the plume sample to acquire a mass loading sufficient for chemical analyses. The changing meteorology over the sampling period did not guarantee that the background sample was uninfluenced by the plume but the winds during the sample period generally placed the background site upwind of the power plant.

Other source chemical fingerprints included the Denver Brown Cloud wood-burning source profile (Watson et al., 1988b), the State of Nevada Air Pollution Study (SNAPS) mobile source profile for automobile emissions (Watson et al., 1988a), the South Coast Air Quality Management District's

Table 1 (continued)
Pleasant Valley Source Apportionment Study
Ambient Measurements^a

<u>Measurement</u>	<u>Sampling Period</u>	<u>Measurement Method/Instrument</u>
PM ₁₀	Daily, 24 Hours/Day	DRI MEDIUM-VOLUME (PM ₁₀) Sampler
Hydrogen Sulfide	Hourly, 24 Hours/Day	Flame Photometric/Meloy 285
Wind Speed	Hourly, 24 Hours/Day	Cup Anemometer/Met One
Wind Direction	Hourly, 24 Hours/Day	Vane/Met One
Sigma Theta	Hourly, 24 Hours/Day	Computed/Campbell 21X
Temperature	Hourly, 24 Hours/Day	Thermistor/Met One
Relative Humidity	Hourly, 24 Hours/Day	Resistance/Met One

^aChow (1987) describes the measurement processes, data processing, and quality assurance procedures.

lime/gypsum and residual oil combustion source profiles (Cooper et al., 1987), and single-constituent source profiles (Watson, 1979) for secondary ammonium sulfate, secondary ammonium nitrate, and secondary organic carbon.

Figure 1 shows the chemical fingerprints of the different emissions sources which are expected to contribute to PM₁₀ concentrations in Pleasant Valley. The power-plant cooling tower contains mostly soluble species such as ammonium, potassium, nitrate, sulfate, and chloride ions. These probably originate from salts dissolved in the water. Copper, zinc, arsenic, bromine, palladium, silver, cadmium, and lead are also found in the plume, but at levels which are much less than 0.01%. The metallic species may have originated in the power-plant plumbing. Others may be dissolved in the water. Arsenic, for example, is often found in Nevada well-water. Some of these species may also have been entrained in the plume from dilution with the ambient air and are not entirely eliminated by the background subtraction. None of these species is present at levels which would be considered deleterious to health. The power-plant plume fingerprint is substantially different from the chemical fingerprints of other sources.

The EPA/DRI Chemical Mass Balance receptor model (Watson et al., 1990) was applied to the PM₁₀ chemical composition measurements following the application and validation protocols of Pace and Watson (1987). After several initial tests, the eight source profiles which were chosen for application to the data sets were: primary soil dust (COMP1, COMP2), primary construction dust (CDLIME), primary motor vehicle exhaust (MVRENO4), primary residual oil combustion (ROILSD), primary plume emissions (PLUME1), secondary ammonium nitrate (NH4NO3), secondary ammonium sulfate (NH4SO4, NH4HSO4), and secondary organic carbon (ORGANICS). The vegetative burning source contribution was small and the omission of this source-type did not change the overall modeling results.

RESULTS AND DISCUSSION

PM₁₀ concentrations were generally low, with an average of $13.8 \pm 7.4 \mu\text{g}/\text{m}^3$ over the sampling period. The highest PM₁₀ concentration of $40.9 \pm 2.1 \mu\text{g}/\text{m}^3$ occurred on 3/22/88 and is much lower than the National Ambient Quality Standard (NAAQS) 24-hour PM₁₀ standard of $150 \mu\text{g}/\text{m}^3$. Among the 41 chemical species which were sought, only those common to geological crustal material (such as

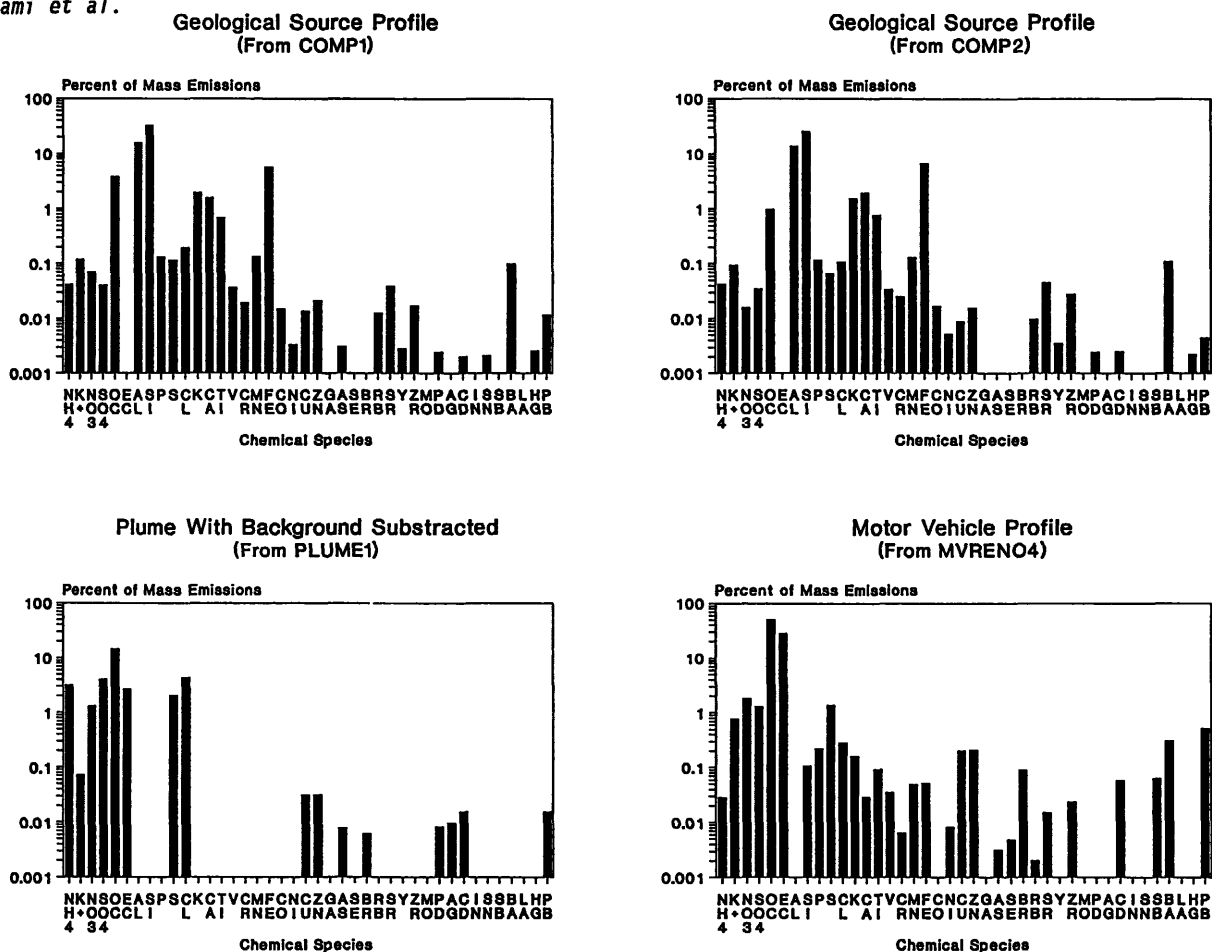


Figure 1. Chemical Source Profiles Applied in the Pleasant Valley Source Apportionment Study. The profiles are: a) Composite Geological Source Profile around the Sampling Site (COMP1), b) Composite Geological Source Profile from the Geothermal Plant (COMP2), c) Cooling-Tower Plume Source Profile (PLUME1) with Background Subtraction, and d) SNAPS Motor Vehicle Source Profile (MVRENO4).

aluminum, silicon, potassium, calcium, and iron), secondary ammonium, nitrate, sulfate, and organic and elemental carbon were found. Most of the other elemental concentrations including toxic species such as mercury, cadmium, arsenic, and selenium, were at or near instrument detection limits. These detection limits are orders of magnitude lower than hazardous levels.

The Chemical Mass Balance receptor model was applied to each 24-hour sample. With the selected source profiles, nearly 100% of the PM_{10} was accounted for within measurement and modeling uncertainties, in over 90% of the cases. The values of all CMB performance measures are well within the criteria range specified in EPA model application and validation protocols (Pace and Watson, 1987).

Figure 2 displays the individual 24-hour source apportionment results for the study period and Figure 3 reports the average source

contribution estimates. Primary geological material was the major source contributor and accounts for 58% or $8.0 \pm 1.4 \mu\text{g}/\text{m}^3$ of the average PM_{10} . Primary motor vehicle exhaust was the second largest source contributor at 17% or $2.3 \pm 0.2 \mu\text{g}/\text{m}^3$ of the average PM_{10} . The geothermal cooling-tower plume was detectable and contributed an average of 9% or $1.3 \pm 0.3 \mu\text{g}/\text{m}^3$ of the average PM_{10} . Primary construction dust, secondary organics, secondary ammonium nitrate, and secondary ammonium sulfate source contributions were small, ranging from 0.3 ± 0.03 to $0.8 \pm 0.2 \mu\text{g}/\text{m}^3$ of the average PM_{10} .

The highest PM_{10} concentration of $40.9 \pm 2.1 \mu\text{g}/\text{m}^3$ was measured on 3/22/88. This value is three times higher than the average PM_{10} concentration of $13.8 \mu\text{g}/\text{m}^3$ over the sampling period. The 24-hour average wind speed on 3/22/88 was 4.8 m/s and the highest hourly average was 10.4 m/s. Over 72% or $2.9 \pm 2.5 \mu\text{g}/\text{m}^3$ of the PM_{10} mass on 3/22/88 was contributed by geological material. No detectable plume contribution was found on this high PM_{10} day.

Geothermal cooling-tower plume contributions ranged from $0.34 \pm 0.49 \mu\text{g}/\text{m}^3$ on 3/19/88 to 3.8 ± 0.93 on 3/28/88. The plume contributions were about three times higher than the average $1.3 \pm 0.3 \mu\text{g}/\text{m}^3$ on 3/27/88, 3/28/88, and 3/29/88, ranging from 3.0 ± 0.7 to $3.8 \pm 0.9 \mu\text{g}/\text{m}^3$. The hourly meteorological data indicate predominantly northerly and northwesterly winds on these days with an average wind speed of 2 to 4 m/s. Hourly average H_2S concentrations in excess of 0.1 ppb were detected 10% of the time on these days, which confirms the plume impact.

The contributions from each of these sources are far below levels which have been found to cause adverse health effects.

CONCLUSIONS

The conclusions to be derived from this study are the following:

- The chemical composition of the geothermal cooling-tower plume consists mostly of sulfate, ammonium, chloride, and some trace elements. The trace elements are metallic in nature and probably derive from the metals used in the power-plant plumbing.

- Average and maximum PM_{10} concentrations measured in Pleasant Valley are much lower than Federal standards. No significant quantities of toxic inorganic species were found in ambient air.
- Resuspended dust contributed over 60%, motor vehicle exhaust contributed approximately 20%, and the geothermal cooling-tower plume contributed less than 10% of the average PM_{10} in ambient air. The absolute concentrations contributed by any source are much lower than those levels which have been found to be deleterious to public health.

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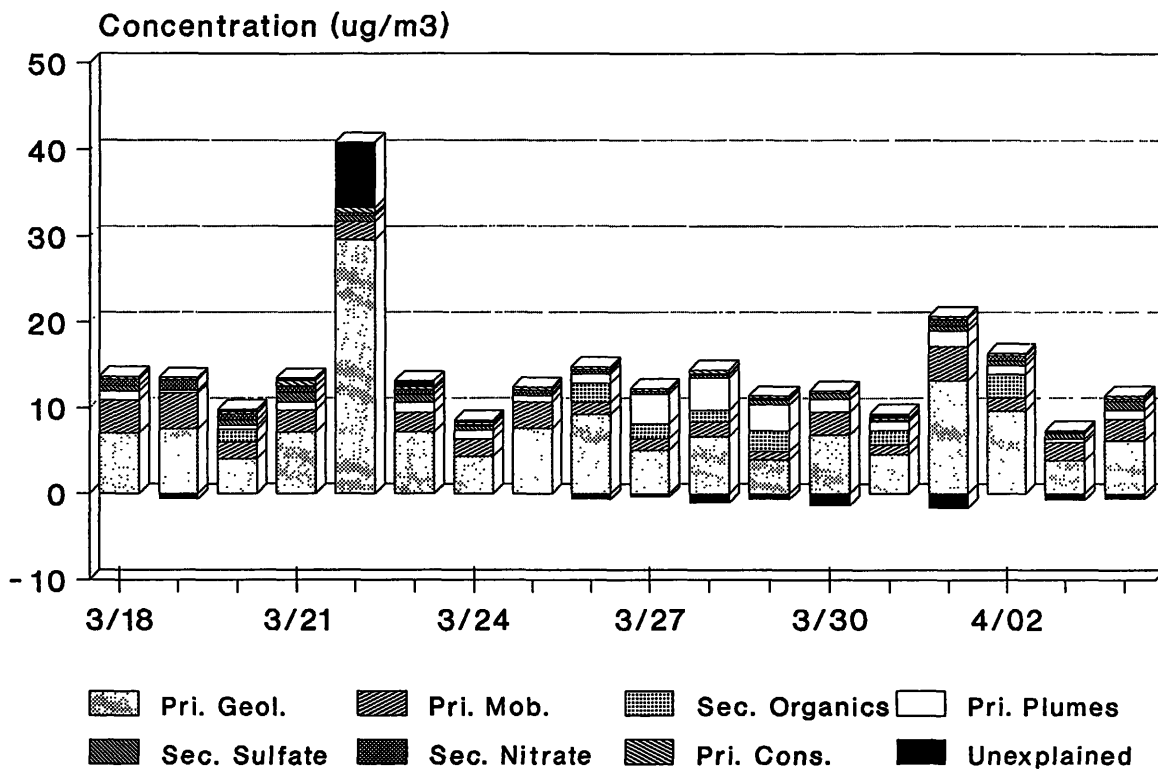


Figure 2. Twenty-four-hour Source Contribution Estimates to PM_{10} for the Pleasant Valley Source Apportionment Study. When the unexplained contribution is positive, the CMB apportionment has not accounted for all contributors to measured mass. When the unexplained contribution is negative, the sum of all contributions exceeds the measured mass. All negative contributions are within calculated and measured uncertainty intervals.

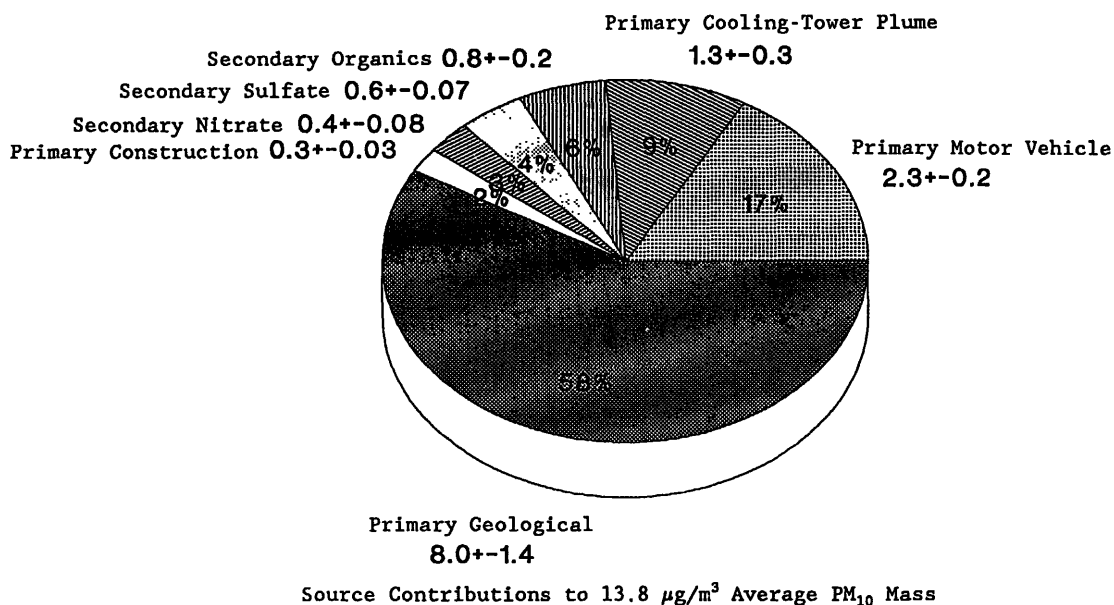


Figure 3. Calculated Source Contributions (µg/m³) to Average Measured PM₁₀ at Pleasant Valley Sampling Site between 3/18/88 and 4/4/88.

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