FINAL REPORT

AMBIENT ASBESTOS CONCENTRATIONS IN CALIFORNIA

Volume I

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ABSTRACT

Measurements of airborne asbestos levels in the state of California were made using a transmission electron microscopic (TEM) analysis of cyclone collected filters. A sampling matrix of ten sites was used to compare asbestos levels from locales containing industrial users, natural mineralogical sources, and heavy traffic braking, with background asbestos levels. Site locations were selected to represent areas of both high and low population exposure.

Extensive monitoring of meteorological conditions, as well as of temporal variations in particulate matter levels, was conducted at each site. Particle monitoring by independent optical detection counters provided measurement of both total mass ($\mu g/m^3$) and particle (numbers/cu. ft) concentration in the 0.3 μm to >5.0 μm aerodynamic diameter range. Site characteristics, meteorological conditions, asbestos levels and particulate matter levels were compared.

Asbestos levels ranged from the analytical detection limit at 'background' sites to slight, but observable elevations in the braking, industrial and urban sites. The highest asbestos levels were in the vicinity of the Union Carbide asbestos mill at King City, representing an area having a substantial localized source; levels there ranged from detection limit up to 140,000 fibers/m^3 of filtered air. All other sites were below 56,000 fibers/m^3, and there were no observable differences found between typical urban locations and a Los Angeles site, the latter considered to represent an area of concentrated automobile traffic braking. In general, differences between 'background' locations and urban or industrial areas consisted of only very slight elevations.

Comparisons of measured asbestos levels with temporal variations in particulate matter levels (total suspended, inhalable, and fine particle concentration data) did not provide any observable correlations after short term (one- to four-hour) sampling.

1.0 SUMMARY AND CONCLUSIONS

This project was conducted in order to measure ambient airborne asbestos concentrations from California's diverse range of potential emission sources. In addition to establishing respirable asbestos concentrations at a cross-section of California locations, other objectives include:

- determining quantitative relationships among meteorological parameters, suspended particulate matter levels and asbestos levels at different locations;
- examining the correlation between OSHA[1]-defined (optical) fiber count measurements and electron microscopic determinations;
- evaluating identified asbestos sources as to their importance in providing a data base for predicting airborne asbestos levels at other locations.

1.1 Findings and Conclusions

The results of this project indicate that measurable, low airborne asbestos concentration levels, usually approaching the minimum detection limit of transmission electron microscopic (TEM) analysis, exist at a number of locations in California. Levels were relatively low at all sites except King City, which is in the vicinity of a localized asbestos source. Overall results indicate distinctions among source locations ranging from areas of minimally elevated asbestos levels from a combination of automobile braking and diverse industrial activities, to sites containing asbestos levels at or below the detection limit of the sampling and analysis techniques used (~2,400 fibers/m^3). Although currently there are no definite guidelines for distinguishing between 'background', 'elevated exposure', and 'high exposure' levels, operational boundaries were used to categorize observed conditions, making no presumption as to potential health effects from exposure.

[1]Occupation Safety and Health Administration

Asbestos levels in the range of 1,000 to 10,000 fibers*/m^3 bracket the lower limit of detection and were considered 'background'. This 'background' is controlled by the low mass concentration of particulate matter in the air and the limitations of filtration equipment relative to sampling parameters. Analytical reliability is poor in the 'background' count range and correlations among data in this range should not be expected to be high.

In the concentration range from 10,000 to 100,000 fibers/m^3, it is possible to differentiate between measurements which are a factor of three to five apart. Measurements in this range were considered to be 'elevated exposure' levels. A number of areas throughout California fell into the 10,000 to 100,000 fibers/m^3 size range, even though they generally do not contain recognized, substantial sources of asbestos. Often, these areas have such elevated levels because of collective emissions from relatively minor sources.

Asbestos levels above 100,000 fibers/m^3 were categorized as 'high exposure' because of the conditions necessary to cause elevations of this magnitude. Assessments of past and present data conducted by state and federal agencies have shown that such levels are always the result of the presence of a substantial point source or local natural deposits.

Table 1.1-1 presents site-averaged total asbestos levels (both chrysotile and amphibole) measured during this project. The mean concentration values are based on all data at or above the detection limit. Further statistical analysis of these data is not possible since weather conditions, traffic and other parameters were so variable at each location. As shown in Table 1.1-1, all sites monitored contain some measurements at or below the minimum detection limit of analysis (~2,400 fibers/m^3). Because of the uncertainty of the actual levels of asbestos in this detection limit range, the

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*The term 'fiber' as a unit of measure in this study is defined as a particle with a length-to-diameter ratio greater than three-to-one. Both the Occupational Health and Safety Administration (OSHA) and the American Conference of Government and Industrial Hygiene (ACGIH) have established fiber length at greater than 5 μm in their proposed industrial health standards for asbestos.

Table 1.1-1. Site Comparison of Mean Asbestos (Chrysotile and Amphibole) Levels (expressed concentration above detection limit).

Site Type	Site Location	Chrysotile Fibers		Amphibole Fibers		Total Asbestos Fibers
		% Samples above D.L. (1)	Mean Concentration (fibers/cubic meter)	% Samples above D.L.(1)	Mean Concentration (fibers/cubic meter)	Mean Concentration (fibers/cubic meter)
Non-Urban	Napa	75%	6,300	50%	5,900	12,200
Urban	San Fernando Valley	75%	19,000	0	<D.L.	19,000
Urban	San Diego	20%	4,500	60%	16,000	20,500
Non-Urban	Bakersfield	50%	29,000	50%	31,000	60,000
Industrial	San Jose	75%	16,000	75%	6,500	22,500
Industrial	South Gate	50%	37,000	75%	29,000	66,000
Vehicle Braking	Century City (Sunday, 10/18/81)	50%	31,000	25%	20,000	51,000
Vehicle Braking	Century City (Monday, 10/19/81)	50%	42,000	0	<D.L.	42,000
Localized Source	King City (Union Carbide)	75%	51,000	0	<D.L.	51,000
Localized Source	Stockton (Manville)	----	18,000 (1 sple)	----	3,700 (1 sple)	21,700
Natural Mineralogical Source	Sonora	75%	7,100	75%	2,400	9,500

(1) D.L. = Detection limit

data are best expressed as mean asbestos levels above detection limit. Also, it should be noted that an average of the samples taken at each site which had levels above detection limit in these measurements represent the maximum fiber amounts measured during the sampling period. This means that values below the detection limit are not included.

1.2 Recommendations

The results of this state-wide asbestos inventory indicate that localized sources are the major potential contributors to population exposure. Future efforts in evaluating the ambient environment should concentrate on the meteorological effects of dispersion and resuspension in the vicinity of such localized sources. A future, more detailed survey of the King City site could fulfill a dual purpose. First, exposure variability at King City should be determined, since this location represents possibly the greatest airborne asbestos source in California. Second, King City could be a suitable model for looking at the mechanisms of asbestos resuspension and the effects of wind speed, humidity, fog and radial distance from a source. This model could provide needed information for evaluating the effects of meteorological conditions on airborne asbestos levels in cities such as Sonora and Mariposa, which are located in the vicinity of natural serpentine asbestos deposits. Soil analyses for asbestos fibers should also be performed, as should ambient monitoring to examine long-term dispersion patterns and resuspension potential.

The results of this study indicate the need for additional investigation at natural serpentine areas such as Sonora and Mariposa. The discrepancy between results from archived samples collected in past surveys, which show asbestos levels much higher than those observed in the present survey (see Section 4.4), are more likely due to differences in mining practices, construction and weather than sampling and analysis techniques.

It is important to analyze samples in the Sonora area taken under a range of TSP levels to determine variations in airborne asbestos concentrations that might occur.

Another topic needing further study is indoor air quality. Internal building spaces are stagnant collection zones where construction material particles can become concentrated. Particle concentration levels inside buildings are commonly two to ten times higher than those found outside, as a result of restricted air flow allowing the accumulation of particles from carpets, ceilings and appliances. Industrial asbestos products also include acoustical ceilings and heating insulation. In traditional occupational monitoring by optical microscopy, asbestos measurements include only the range of fibers which are longer than 5.0 μm. However, SAI surveys using electron microscopy show that 90 to 95% of asbestos fibers in the ambient environment are shorter than 5.0 μm.

Since from the available data, no direct correlations can be drawn between optical and electron microscopy, such a comparison should be conducted. With the growing number of enclosed buildings such as large shopping malls and offices, more and more people are exposed to abnormal particle concentrations. Unfortunately, there are only limited TEM data from such settings to confirm the occurrence of asbestos. An important contribution of the survey described in this report is the establishment of an outdoor baseline to evaluate indoor exposure in the context of background asbestos levels in the air. Monitoring indoor spaces is needed to fill a critical gap in population exposure assessment not covered in this ambient survey nor by traditional occupational monitoring.

A final recommendation is to include the reporting of fiber surface area ($\mu m^2/m^3$) with mass and fiber concentration results. Although this parameter is not presently being evaluated, it could provide valuable epidemiological information for future studies, and is relatively easy to include in a computer program. The fiber surface area provides the potential tissue contact. Such information has been provided in the data appendix to this report.

2.0 PROJECT BACKGROUND

2.1 Airborne Asbestos in California

Natural Sources

Asbestos is a mineral fiber widely produced and used in California. Naturally occurring asbestos fiber deposits are widely distributed throughout the state; Figure 2.1-1 illustrates the geographical range of the minerals sources. Two California deposits are sufficiently rich and extensive to warrant commercial exploitation. Of the five mine and mill operations in the U.S., three are in California, two are located at the junction of Fresno, San Benito and Monterey Counties, and the third is centered near the Sonora area of Calaveras and Tuolumne Counties (Figures 2.1-2 and 2.1-3). Most of the state's naturally occurring asbestos deposits are located in the extensive serpentine and peridotite formations of north central California.

Anthropogenic Point Sources

In California, most asbestos users are registered with federal and/or state agencies and can be identified in the state Occupational Cancer Control Unit (OCCU) files and in the U.S. Environmental Protection Agency's list of materials which are regulated under the National Emission Standards for Hazardous Air Pollutants (NESHAP). It has been estimated by the OCCU that there may be over 3000 state-wide industrial asbestos users, reported and unreported, under a variety of standard industrial classification (SIC) codes. Presumably, their geographic distributions reflect the state's overall industrial density.

Sources Related to Distribution of Asbestos-Containing Materials

Besides asbestos emissions from natural mineralogical deposits and identifiable localized sources, there are other sources which potentially

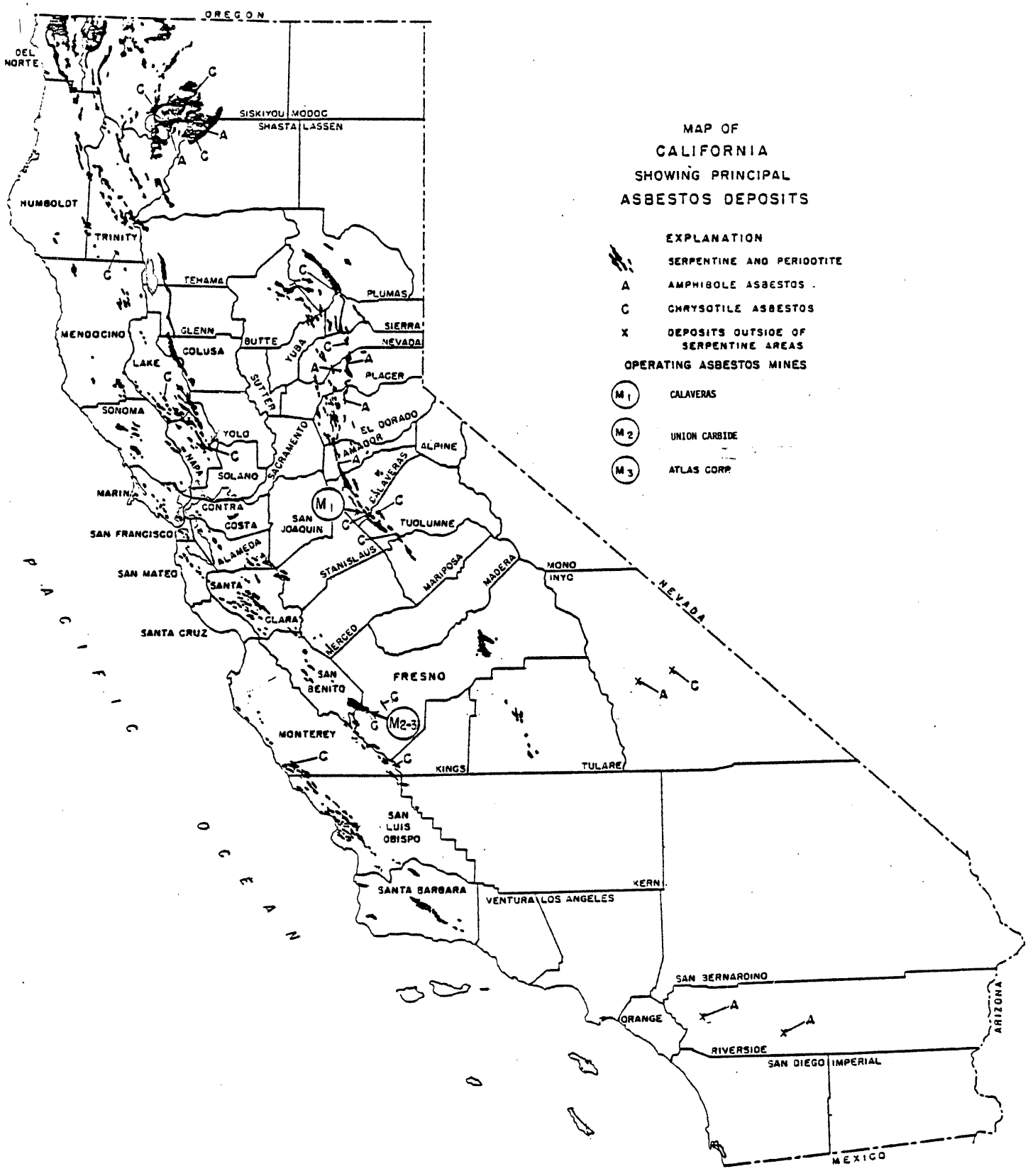


Figure 2.1-1. Geographical Distribution of Asbestos Deposits throughout the State of California.

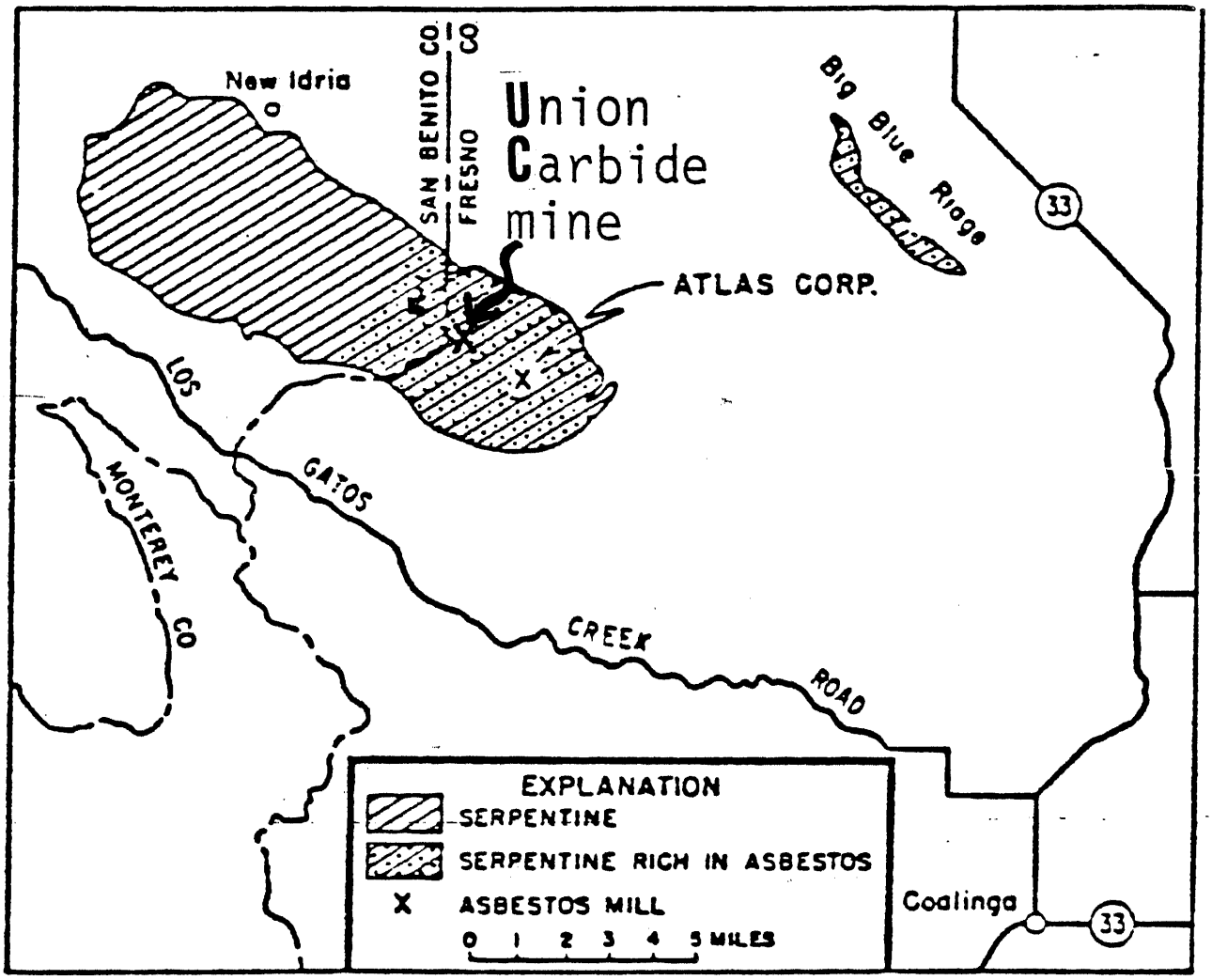


Figure 2.1-2. Fresno County Asbestos Deposits, Mines and Mills (vicinity of Coalinga).

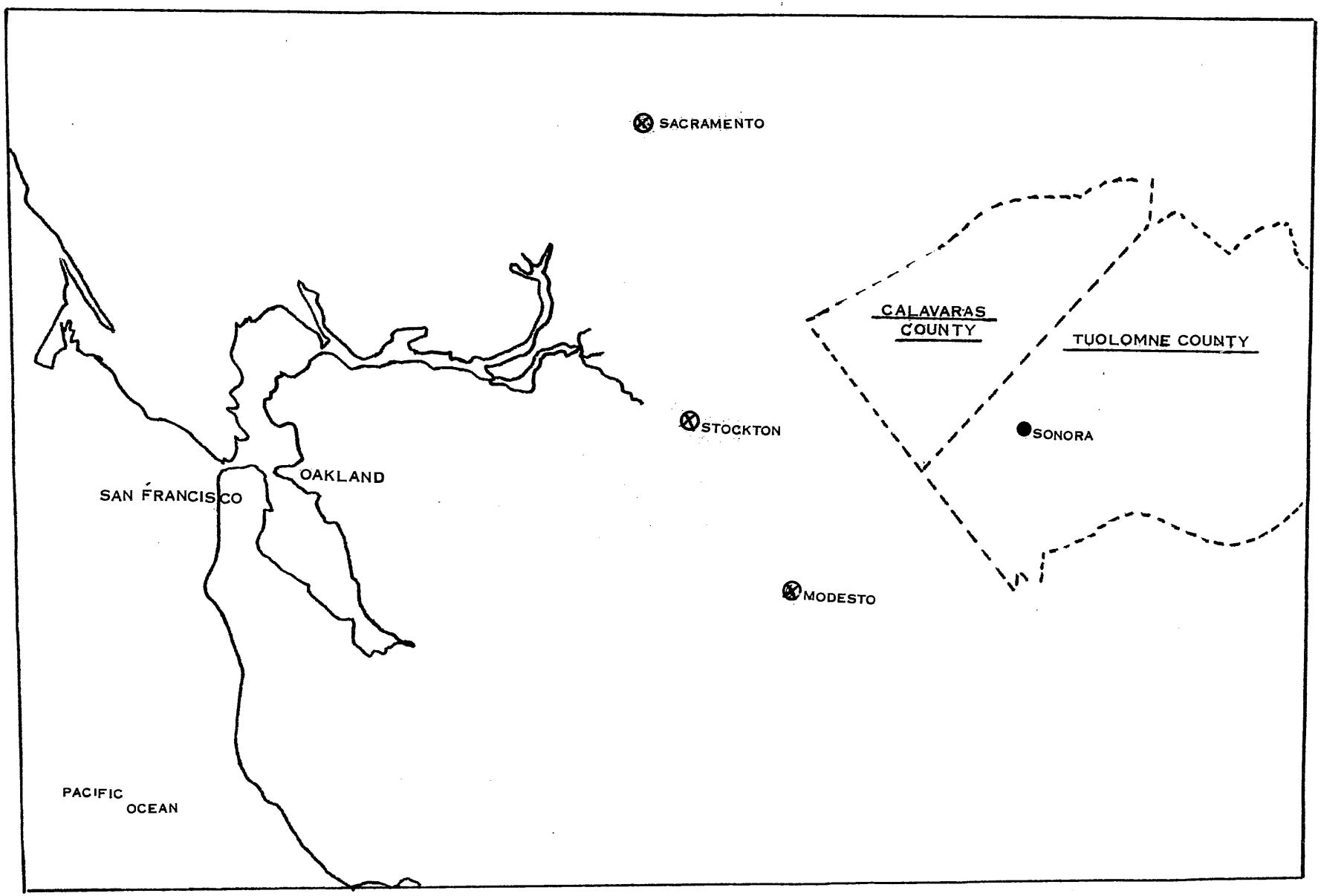


Figure 2.1-3. Calaveras and Tuolomne Counties.

contribute to the total exposure received by California's population. These include degradation of asbestos products, such as vehicle brake lining materials, textiles and insulation materials, and the demolition of buildings containing such asbestos products as insulation, cement sheet, roofing and floor tiles. These activities and emissions from industrial users generally support urban background levels of asbestos.

Transportation and handling of milled asbestos fibers in pellet form is becoming prevalent, helping to reduce the amounts of asbestos in the air. Also, conversion by manufacturers away from the use of asbestos materials in their products is underway. The National Workshop on Substitutes for Asbestos, jointly sponsored by the U.S. EPA and the Consumer Product Safety Commission, has reviewed asbestos substitutes in products such as friction materials, gaskets and packings, plastics, paper, roofing products, textiles, sealants, roof coatings, asbestos cement sheet and asbestos cement pipe (EPA, 1980). In most areas, active substitution has been proceeding.

Importance of Airborne Asbestos

The National Cancer Institute (1978) has identified the following categories of asbestos sources as contributors to populational exposure:

1. Asbestos mining, milling and product manufacture
2. Transportation of materials containing asbestos
3. Asbestos manufactured products
4. Disposal of asbestos products and wastes
5. Asbestos in foods and drugs

The relative importance of these categories has been changing significantly because of controls on asbestos-related industries and shifts in use patterns. However, according to the National Cancer Institute (1978): "Because asbestos is exceptionally resistant to thermal and chemical degradation, it persists in

the environment and can be widely redistributed by both natural forces and human means." Also important: "Asbestos fibers . . . usually have negligible gravitational settling properties, and are easily re-entrained at ground surfaces." (EPA, 1978a)

An important implication is that more airborne asbestos may be found in areas around known emission sources and may be affecting large populations. Whether or not there are higher airborne asbestos levels in areas of California having natural deposits of asbestos is not known. Also, anthropogenic dispersion and meteorological controls (wind and moisture) are likely to play key roles in elevating airborne levels of asbestos above desirable limits.

Table 2.1-1 summarizes fiber concentrations previously measured by electron microscopy, from which a number of observations can be made:

1. Fiber concentrations immediately upwind and downwind of heavy traffic have not convincingly indicated that vehicle friction materials represent a significant asbestos source. In recent years, all major brake material manufacturers have initiated programs phasing out asbestos in disc and drum brake materials (Ziskind et al., 1979).

2. Airborne asbestos concentrations at San Lucas, California, approximately five miles downwind from a commercial asbestos processing mill, were considerably higher than those at other sites in the state (Ziskind et al., 1982a).

3. Very few data exist to establish airborne asbestos levels in the vicinity of naturally occurring asbestos deposits.

Other data, such as fiber sizes, although of interest, are not available from this reference.

In addition, two groups have recently evaluated airborne asbestos concentrations in the vicinity of serpentine formations. PEDCO Environmental, Inc. (1980) sampled the New Idria deposit (at Clear Creek) and the Sonora area to assess emissions from unpaved roads and reported the data to EPA. Results of the TEM analyses (EPA, May 1981) of the samples analyzed according to EPA

Table 2.1-1 Ambient Asbestos Measurements in California (from Margler, 1979).

Location in California	Number of Fibers/m^3	References
King City, downwind of a milling plant	6,000 to 1,600,000	John et al., 1976
King City, upwind of a milling plant	200 to 11,000	John et al., 1976
San Jose	0 to 3,500	Murchio et al., 1973
Berkeley	0 to 4,000	Murchio et al., 1973
Los Angeles (Downtown)	0 to 5,700	Murchio et al., 1973
Emeryville, near asbestos manufacturer	238,000	Murchio et al., 1973
White Mountain (desert)	20 to 100	Murchio et al., 1973
Santa Monica Freeway, upwind (at 4th)	700*	Murchio et al., 1973
Santa Monica Freeway, downwind (at 4th)	700*	Murchio et al., 1973
Harbor Freeway, upwind (at 146th)	1,100*	Murchio et al., 1973
Harbor Freeway, downwind (at 146th)	1,600*	Murchio et al., 1973
San Diego Freeway, upwind (at National)	200*	Murchio et al., 1973
San Diego Freeway, downwind (at National)	800*	Murchio et al., 1973
San Diego Freeway, upwind (at 122nd)	900*	Murchio et al., 1973
San Diego Freeway, downwind (at 122nd)	500*	Murchio et al., 1973
Los Angeles Freeways, upwind (four sites)	800**	Murchio et al., 1973
Los Angeles Freeways, downwind (four sites)	900**	Murchio et al., 1973
San Lucas	1,000,000	Wesolowski, 1975
Berkeley	700,000	Wesolowski, 1975

* Mean values

** Mean value of 60 samples

protocol (EPA-600/2-77-178) by the Ontario Research Foundation and the Denver Research Institute ranged from approximately 40,00 to 2,900,000 total asbestos fibers/m^3.

Science Applications, Inc. (SAI) analyzed archived high volume filters collected during 1976 to 1980 from the Sonora and Mariposa areas (Ziskind et al., 1982a). Results from these analyses, performed by scanning electron miscroscopy (SEM) and discussed in Section 4.4, indicate that asbestos levels ranged from 86,000 to 1,000,000 total fibers/m^3 (<5.0 μm long) and 9,500 fibers/m^3 to 448,000 fibers/m^3 (>5.0 μm long).

2.2 Project Objectives

Asbestos has been linked to cancer in humans, and many occupational health experts believe that there may not be a safe-use threshold level for it. Accurate sampling and analysis of air for asbestos contents is not yet routine, although advancements have been made to the point that measurement programs can produce reliable, representative concentration data.

The major objective of this project has been to quantitatively establish an important data base of airborne asbestos concentrations, in the respirable ranges in California. By having complementary knowledge of confirmed and potential sources, emissions mechanisms, relevant meteorological conditions and particle concentration levels, quantitative relationships between sources, conditions and observed concentrations should be identifiable.

As stated in the CARB's original project objectives, "The ultimate goal of the project is to establish 'worst case' respirable asbestos concentrations in a representative cross-section of California locations". Other objectives include:

- Determining quantitative relationships among meteorological parameters, total suspended particulate matter (TSP) levels and asbestos levels at different locations.

- Examining relationships between OSHA-defined (optical) fiber counts and electron microscope determinations.

- Evaluating identified asbestos sources as to their importance in providing a data base for predicting airborne asbestos levels at other locations.

2.3 Technical Approach

Given the project objective of providing an inventory of respirable airborne asbestos in California, the technical approach focused on applying state-of-the-art sampling and analysis techniques to a cross-section of geographical sites based on emission/exposure potential. Sampling methods adopted for this study followed protocols established by John et al. (1976, 1978, 1980). No exceptions were taken to the measurement and verification procedures specified by the U.S. Environmental Protection Agency (EPA) 1978b). Discussions with California Air Industrial Hygiene Laboratory (AIHL), U.S. EPA and National Bureau of Standards (NBS) staff resulted in a number of minor changes and improvements.

To accomplish program objective for quantifying asbestos fibers in the respirable range (less than 3.5 μm aerodynamic diameter), a single-point cyclone sampler with a collection efficiency of 50% for 3.5-μm aerodynamic diameter particles at a flow rate of 15.4 L/min was used for all filter sampling. An 8.0-μm pore size backing filter was used in conjunction with a 0.2-μm pore size collection filter. Although original protocols specified the use of a 0.4-μm pore size collection filter, the 0.2-μm pore size filter was chosen for better collection efficiency of smaller fibers. No other significant changes were incorporated.

The cyclone sampler was developed for ambient air size-selective monitoring (Figure 2.3-1). This sampler will collect particles as small as 2.5 μm (21.7 L/min flow); Figure 2.3-2 (from John et al., 1978) indicates the particle deposition efficiency, relative to 50% cutoff, of the cyclone design shown in Figure 2.3-1. Design criteria for the sampler include:

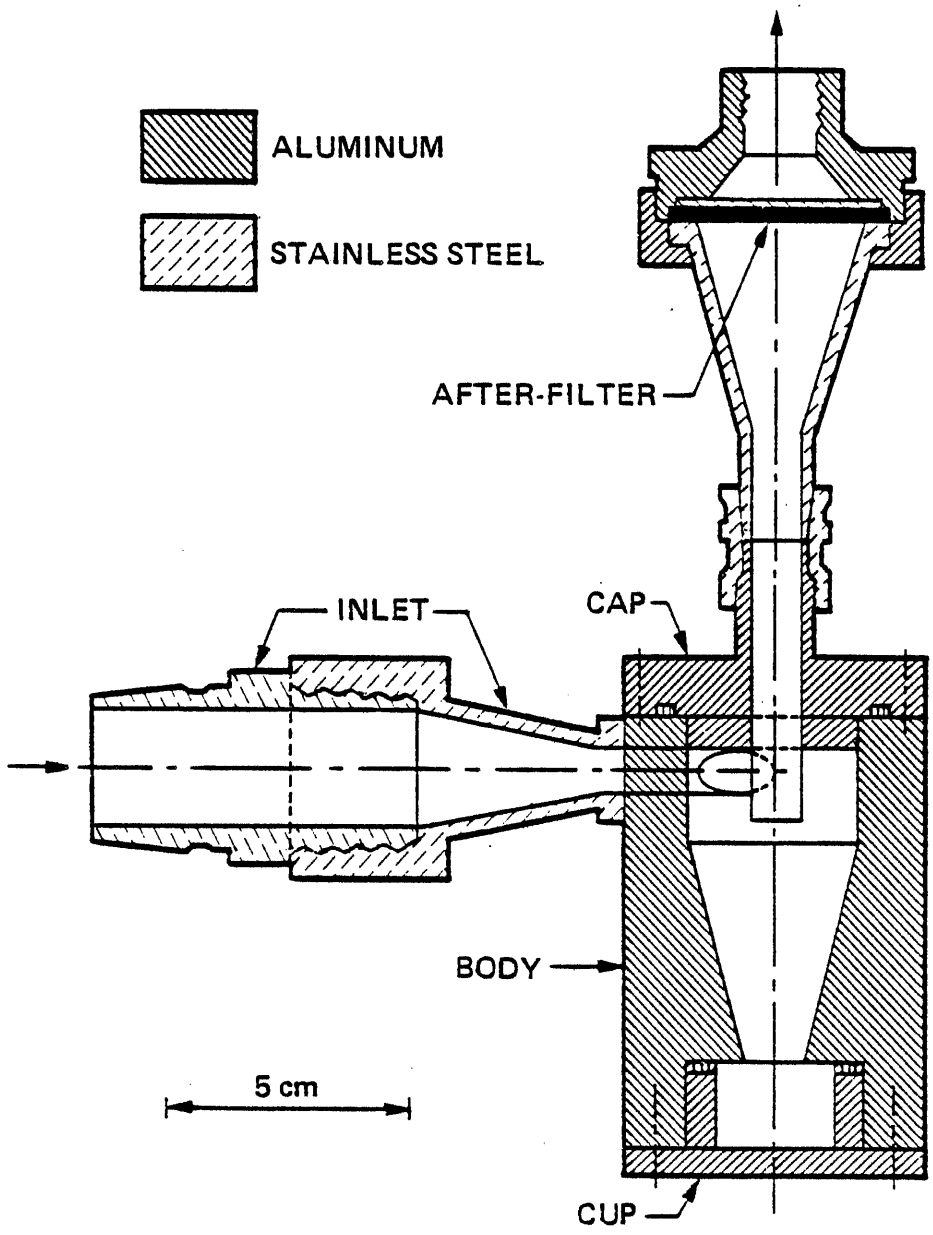


FIGURE 2.3.1 ASSEMBLY DRAWING OF THE CYCLONE SAMPLER DEVELOPED FOR AMBIENT AIR MONITORING (John and Reischl, 1980).

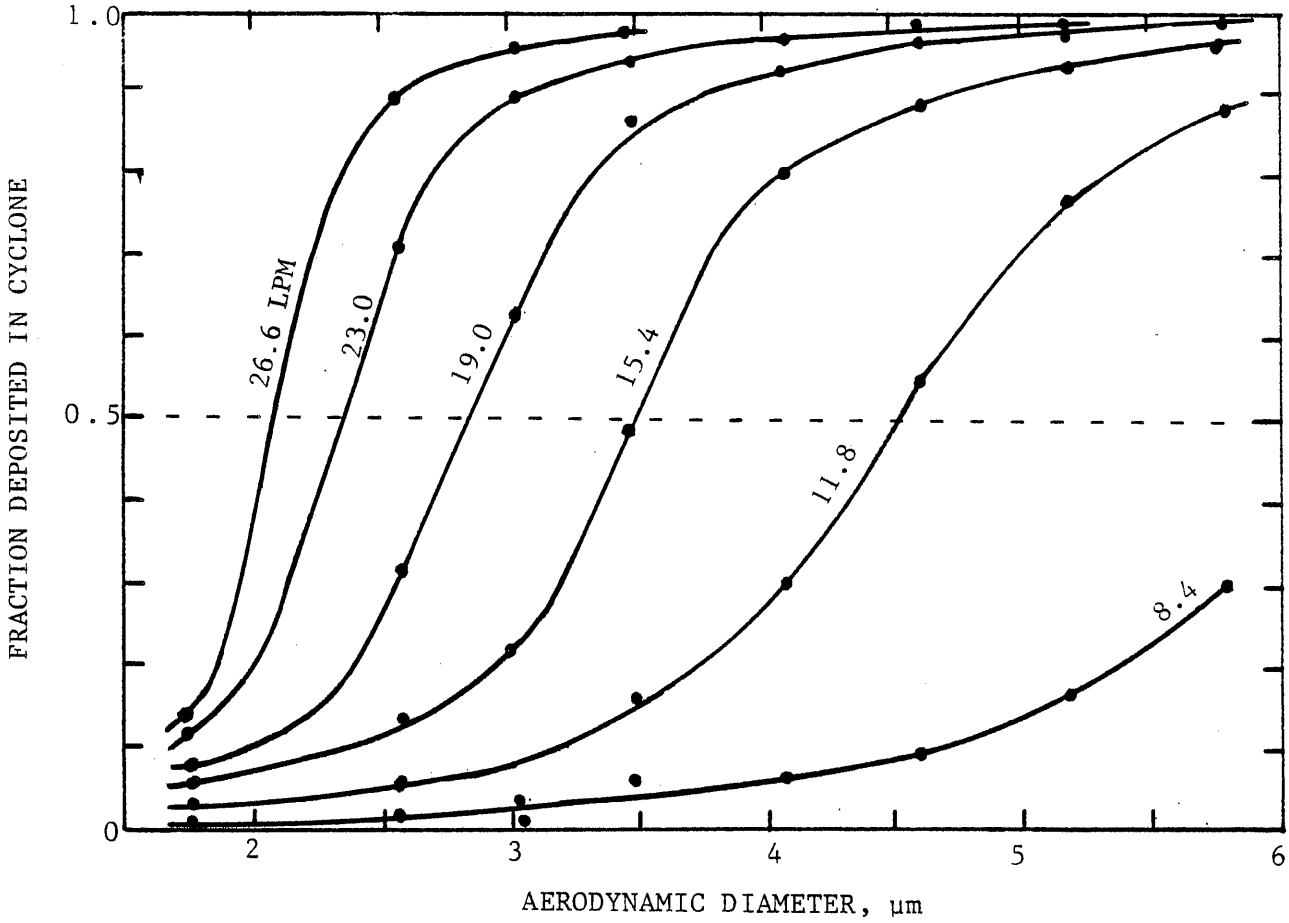


FIGURE 2.3-2. Fraction of Methylene Blue Particles Deposited in the Cyclone as a Function of the Aerodynamic Particle Diameter. The curves are labeled with the flow rate (from John et al., 1978).

- A vertical cone with cap at bottom and outlet on top. This configuration minimizes loading and reentrainment.
- The after filters are 47 mm diameter which will allow the use of membrane filters, if chemical analysis is desired.
- The cyclone is intended for 24 hr sampling at average flows of 15 to 20 l/min.
- Both liquid and solid particles can be sampled with this device.

The cyclone was selected for use over other samplers for this study because of its ease of use in the field, its ability to selectively sample small particles and the design which allows for uniform particle deposit on the filter.

To examine maximum asbestos level conditions, sampling was done during the dry period of the year, when particles are most susceptible to airborne suspension. Also considered was the fact that small scale temporal variations in measurable levels would be important in determining 'worst case' conditions. Rahn et al. (1971) quantified temporal variations in aerosol trace elements, finding that a factor of ten variation can be common over a typical day. The complication that this presents is the uncertainty of comparing 24-hr suspended particle concentration data with several-hour asbestos samples. To adequately derive useful correlations between total particle and asbestos concentrations, extensive real-time particle count data were obtained for the duration of each asbestos sampling period.

This project was intended to measure airborne asbestos concentrations in areas that are known or are suspected to have elevated levels and in those that are isolated from asbestos sources. An additional site criterion was to co-locate, where possible, field measurements with existing particulate matter monitoring stations. In one case, for example, a field site was able to be centrally located in San Jose among 86 registered asbestos users and adjacent to an inhalable particle monitoring stations. Another site (Bakersfield) was chosen in proximity to the inhalable particle station, but isolated from three

registered asbestos users located in the general vicinity. Dispersed throughout California are a number of these fixed monitoring stations, forming a network, which are maintained primarily by regional air quality management districts (AQMDs) and the CARB. These stations are designed to collect by high volume filtering either total suspended particles (TSP), inhalable particles (IP; <15-μm aerodynamic diameter) or fine particles (FP; <2.5-μm aerodynamic diameter).

3.0 METHODOLOGY

3.1 Site Selection

Selection of sampling sites was done relative to six categories related to source type and potential population exposure:

1) Natural Deposits - areas where the soil is a source of asbestos fibers.

2) Localized Sources - locations at or near which asbestos ore is processed, refined or otherwise used, and at which asbestos can potentially be released at elevated levels into the air.

3) Metropolitan Industrial Sources - metropolitan areas which have high density clusters of asbestos users, as identified in the U.S. EPA's registry of sources regulated under the National Emission Standards for Hazardous Air Pollutants (NESHAP).

4) Urban Locations - areas of potentially high population exposure to elevated particulate matter.

5) Non-Urban Locations (Rural) - areas of low population and which are away from metropolitan asbestos emissions and natural asbestos deposits.

6) Vehicular Braking - areas where asbestos emissions from automobile brake and clutch friction materials are expected to be high.

Natural Deposit Site

A 'natural source' site was selected at Sonora (in Tuolumne County; Figure 3.1-1) from the serpentine-rich deposits of north central California (Figure 2.1-1). Sampling was performed at the Tuolumne County Administration Building (Washington and Jackson Streets). The Sonora area is the only one of the three rich serpentine deposits not having active mining operations, deposits in Calaveras County and at New Idria (in San Benito County) being the two that do.

Figure 3.1-1. California Map Showing Locations of the Ten Sampling Sites Used in the CARB Statewide Asbestos Inventory.

Recent electron microscopic analysis of archived high volume filters from Calaveras (located approximately 21 miles west of Sonora, just outside of the town of Copperopolis, CA) dating back to 1976 revealed airborne asbestos concentration in excess of 100,000 fibers/m^3 for that area (Ziskind et al., 1982a). The New Idria mining area is relatively remote from population centers, although the nearby Clear Creek Recreational Area has been suggested to be a potential soil disturbance source from the use of off-road vehicles (Cooper et al., 1979).

Localized Source Sites

In California, localized sources of asbestos can be found in urban, suburban and rural areas. Urban sources, generally registered industrial users, are considered in the subsequent two site categories; two representative rural/suburban sources were chosen, to represent a 'local source' category. The Union Carbide mill at King City (Figure 3.1-1) is an asbestos ore processing plant which is included in the AIHL data base (Margler et al., 1979; Table 2.1-1) for both King City and San Lucas (a nearby downwind location). Table 2.1-1 shows that readings from this area were significantly elevated compared to others. However, since these data were collected over six years ago, considerable differences might be expected as a result of changes in operating practices (dust control measures), meteorology, and storage of asbestos ore, although very little new control technology has been added. This site is located in a rural area that is proximal to only the one asbestos source.

The Manville asbestos cement manufacturing plant is located in Stockton (Figure 3.1-1), one mile from the local airport meteorological station. Prior to a stack and fugitive emission monitoring program undertaken as part of a separate CARB-sponsored project on carcinogenic emissions, only a conservative asbestos emission factor was available for this site (Ziskind et al., 1982b). As part of that survey, simultaneous upwind and downwind airborne asbestos sampling was performed inside plant boundaries. Results ob-

tained provided an assessment of the potential emissions from this source, which is located at the border of an urban area. No other asbestos sources were identified in the vicinity.

Industrial Source Sites

Areas of the state containing the greatest densities of registered asbestos users were identified in an effort to estimate the relative asbestos contributions from these sources to ambient air quality. Eighty-six asbestos users were identified in the San Jose area and 147 in the Los Angeles area. These two areas are not generally influenced by strong flows of marine air. The San Jose sampling site (Figure 3.1-1) was located adjacent to an inhalable particle monitoring station. No previously established monitoring stations were available in the Los Angeles area, however a sampling site was selected adjacent to the Compton/Gardena/South Gate area (Figure 3.1-1), which represents a dense cluster of asbestos users (Table 3.1-1).

Urban Exposure Sites

Urban sites were selected to reflect a variety of climatological conditions and were located away from both serpentine deposits and heavy automobile traffic. This minimized any matrix effects from industrial sources and naturally occurring asbestos deposits or from vehicular braking. As a result, two sites were chosen (Figure 3.1-1): Los Angeles (Sherman Oaks in the San Fernando Valley) and San Diego (San Diego State University). Although neither site was in immediate proximity to an inhalable particulate matter monitoring station, both had total suspended particle monitoring stations nearby. Also, each site was located away from heavy traffic arteries (avoiding first order vehicle emissions) and away from any identified asbestos users. There were fewer than three 'asbestos use sources' in each of these two communities.

Table 3.1-1 Distribution of Identified Asbestos Users in the Los Angeles Area under the U.S. EPA's NESHAP* Registration.

CITY	NUMBER OF ASBESTOS SITES REGISTERED
Bell Gardens	2
Beverly Hills	6
Compton	23
Cudahy	1
Culver City	8
Downey	8
El Segundo	8
Gardena	31
Hawthorne	14
Huntington Park	10
Hollydale	1
Lawndale	2
Los Angeles	3
Lynwood	4
Manhattan Beach	3
Marina Del Rey	1
Maywood	1
Playa Del Rey	2
Redondo Beach	6
Rolling Hills Estates	1
South Gate	10
Willowbrook	1
	147

*NESHAP = National Emission Standards of Hazardous Air Pollutants

Non-Urban Exposure Sites

To contrast urban sites, two non-urban locations were chosen: Oildale (a suburb of Bakersfield) and Napa (Figure 3.1-1). These sites represent different climatological settings, especially relative to dominant wind patterns. Each is in a non-serpentine, rural area having few, if any, identified potential sources of asbestos. The Bakersfield site is located adjacent to an inhalable particulate matter monitoring station.

Vehicular Braking Sites

One of the major historical uses of asbestos has been as frictional material in vehicle brake and clutch facings. Although asbestos substitutes have become increasingly prevalent, asbestos is still in limited use, and it has not been established whether exposure due to such sources can be neglected. Since data from most sites could be subject to uncertain vehicle asbestos contribution, a heavy traffic braking site was selected in Los Angeles to quantify the potential importance of this source. The Century City (Los Angeles) site was located at the intersection of Santa Monica Blvd and Avenue of the Stars (Figure 3.1-1).

In order to duplicate meteorological conditions at this site, monitoring was done on an adjacent Sunday (10/18/81; as a low traffic control) and Monday (10/19/81; high traffic). Traffic counts between the two days were anticipated to vary by at least an order of magnitude.

3.2 Sampling Techniques

Field sampling for asbestos fibers required the integration of filter collection techniques with close monitoring of all conditions which might affect levels of asbestos in the air. As described, sites were chosen to reflect certain source conditions, as well as a range of meteorological conditions. A goal of the project was to document temporal variations at each site

and to relate them to the filter-collected asbestos samples. To accomplish this, an on-site weather tower and an optical particle counter were used in conjunction with cyclone filter sampling. Also data from the CARB, the U.S. EPA and suspended particle monitoring stations were obtained. Eight-hour sampling periods (usually 8:00 a.m. to 4:00 p.m.) were used to adequately observe short-term variability among asbestos and particle concentration levels.

3.2.1 Field Equipment

Meteorological Instrumentation

A Climatronics® portable field weather station (Figure 3.2-1) was used to record temperature, wind speed and wind direction. At certain sites a 30-ft tower was used to support the weather station for added elevation (see Section 4.0 site details). Relative humidity at the asbestos sample filter inlets was measured with a sling psychrometer.

Filter Collection Train

To filter air for asbestos measurement, a pair of single-point, size-selective cyclone filter assemblies designed at the California Air Industrial Hygiene Laboratory (John et al., 1976) was used. The cyclones and the sampling pumps used in filter collection were built by Sierra Instruments. The 'constant flow' pumps continually adjusted their own speed by detecting changes in back-pressure. The cyclone samplers had a collection efficiency of 50% for 3.5-μm aerodynamic diameter particles at 15.4 L/min. Briggs and Stratton® 3000-watt generators were used in locations where electricity was unavailable.

Particle Concentration Monitoring Systems

Two particle counting systems were used to collect ambient suspended particle concentration data. One of these, a Royco® Model 225 particle coun-

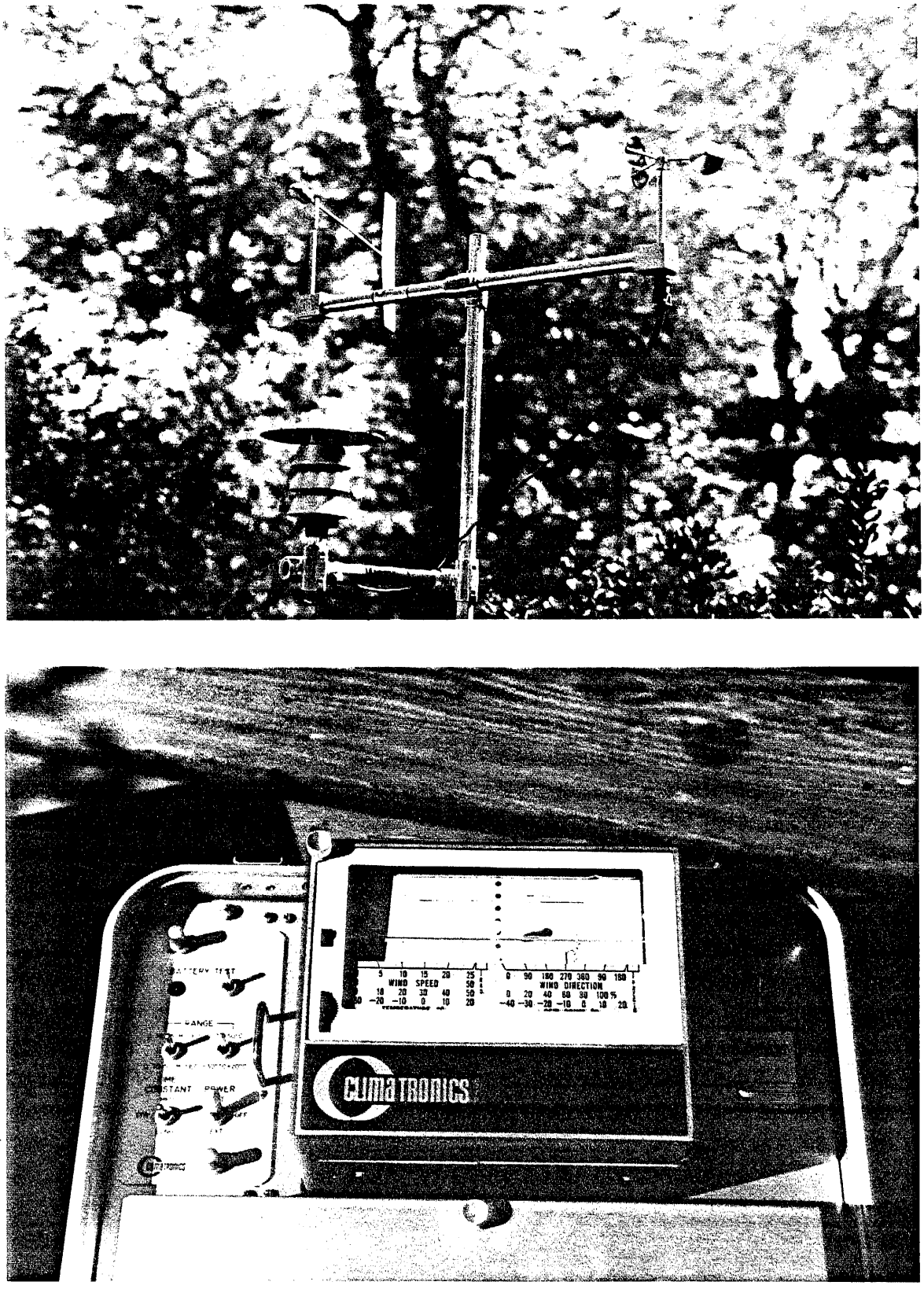


Figure 3.2-1. Top Photo: Climatronics ® Weather Station Sensors.

Bottom Photo: Climatronics ® Weather Station Chart Unit.

ter (Figure 3.2-2), capable of detecting particles as small as 0.3-µm aerodynamic diameter, provided size distributions as well as concentrations (particles/cu. ft) in the respirable size range (<15 µm diameter). The Royco® selectively sizes particles in >0.3 µm, >0.7 µm, >1.4 µm, >3.0 µm, and >5.0 µm aerodynamic diameter categories, the effective upper diameter of countable particles being 20 µm. Using a quartz halogen source, the Royco® works on the principle of light intensity scattering to detect particles in an air stream, generating electronic signal pulses proportional to the quantity and size of the particles. The sampling flow rate of the Royco® is 2.83 L/min.

The second counting system was a RAM-1® optical mass counter from GCA Corporation. The RAM® counter (Figures 3.2-3) uses infrared radiation backscattering to measure total suspended particle amounts, converting its detection to $\mu g/m^3$ of air. Using an Arizona road dust standard, calibration of the RAM® was performed in a factory test chamber, and by matching calibration data with that from a filter sample, mass concentration ($\mu g/m^3$) can be determined. The RAM® is equipped with a cyclone collector that allows for differentiation of particle size, with a size collection efficiency identical to the asbestos sampling cyclones (50% for 3.5-µm diameter particles). Figure 3.2-3 shows the RAM® counter with the cyclone attached (at point A). The sampling flow rate of the RAM® is 2.0 L/min.

3.2.2 Sampling Procedures

Preparation and Handling of Filters

To reduce contamination from handling in the field, individual polyethelyene cassettes were constructed to hold the backing and collection filters for each sample. These cassettes consisted of two rings that press-fit together to provide a rigid support for the filters. Before loading the filters, the cassettes were pre-washed in an ultrasonic bath of 0.1-µm filtered, de-ionized water and allowed to dry in a "particle-free" clean room (class 100 certified; Figure 3.2-4). The filters were loaded into the

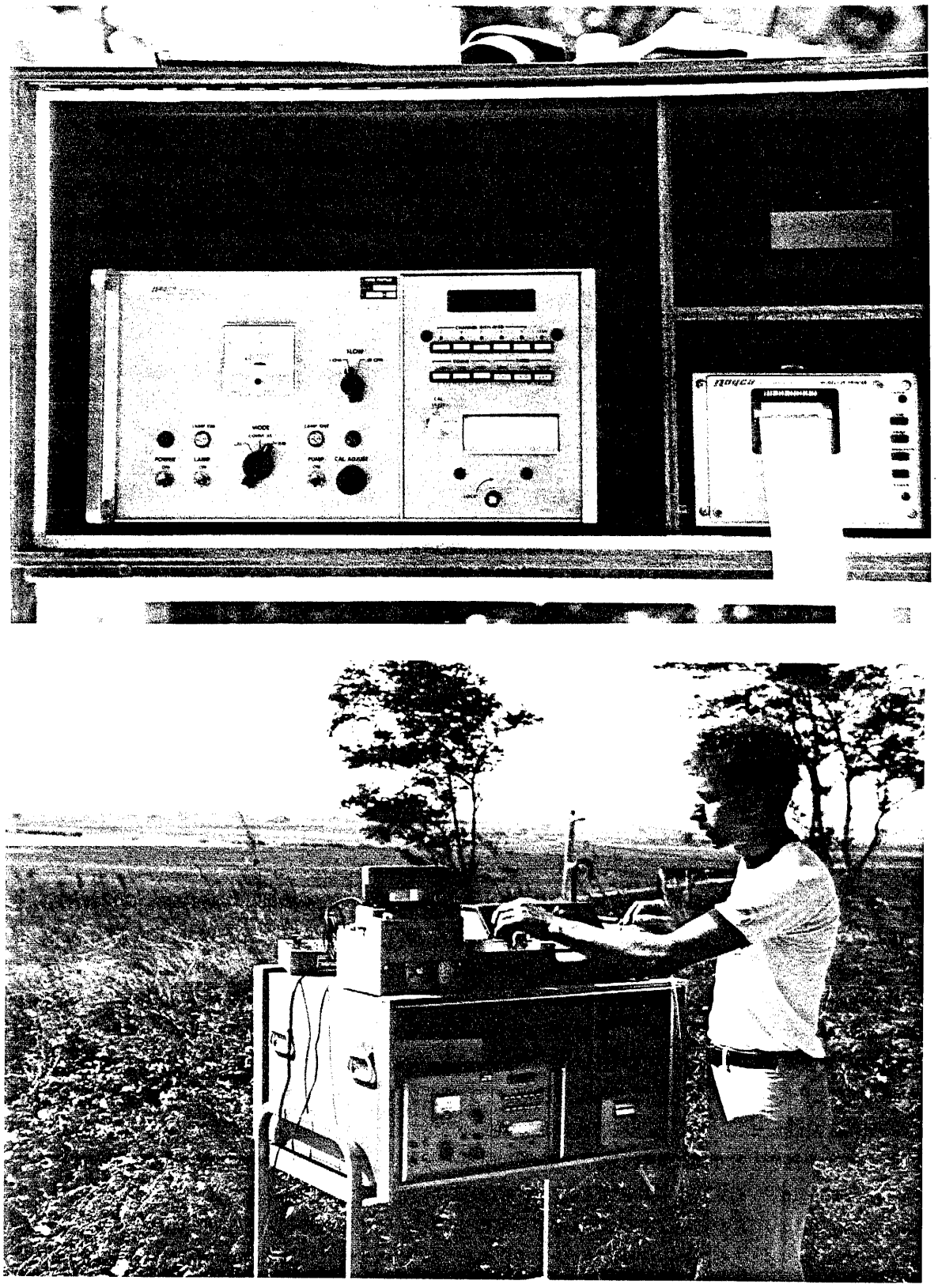


Figure 3.2-2. Particle Matter Monitoring

Top Photo: Royco ® Particle Counter with Automatic Printer.

Bottom Photo: Particle Monitoring Instrumentation.

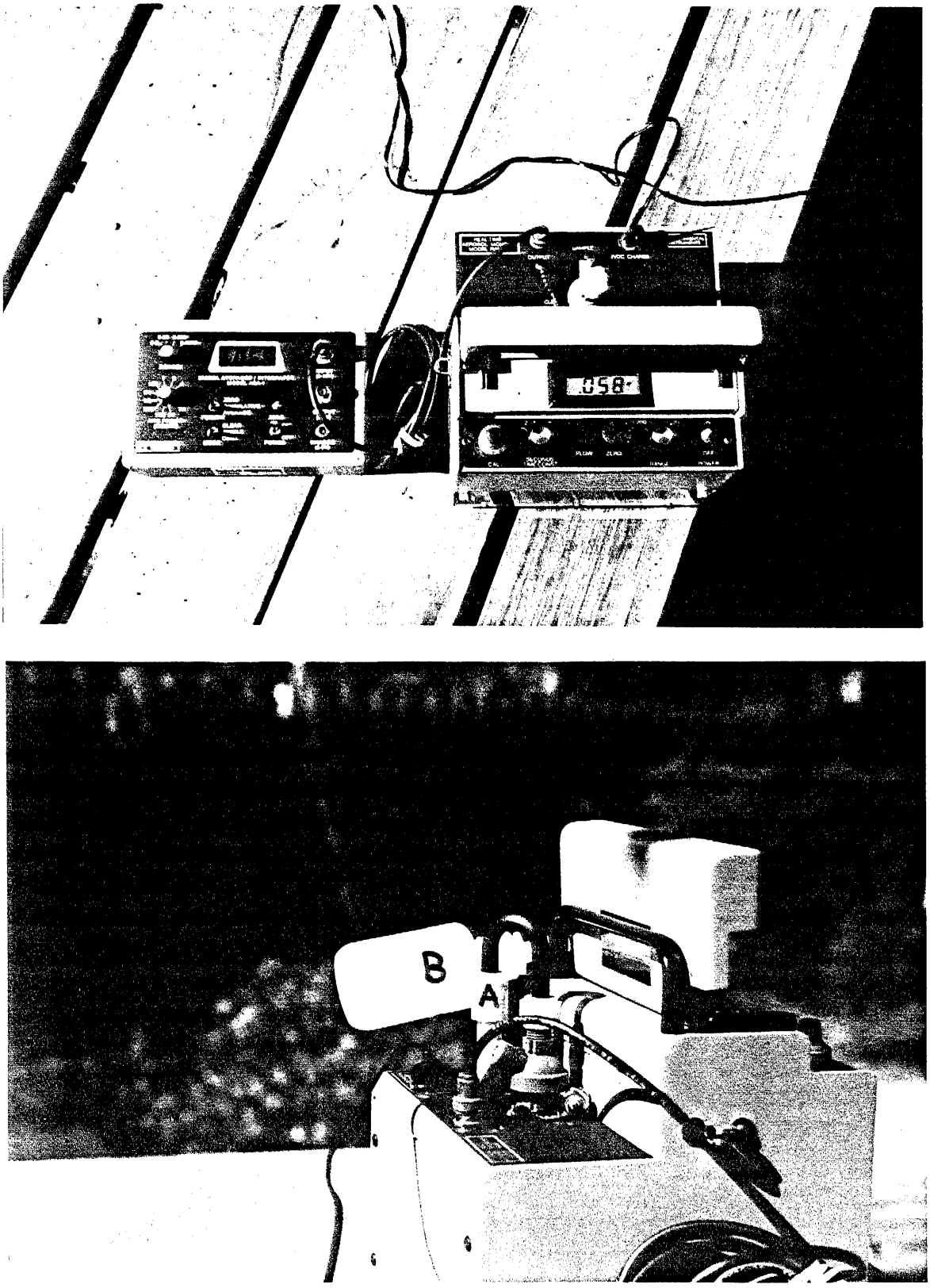
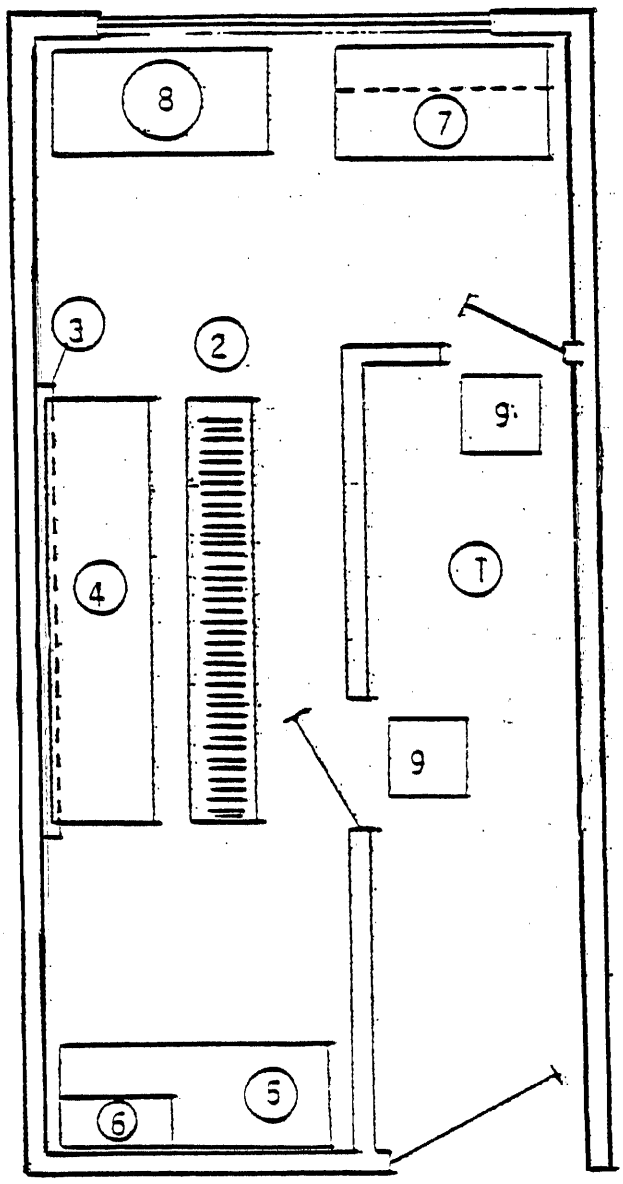


Figure 3.2-3. Top Photo: RAM ® Mass Counter and Integrator.

Bottom Photo: RAM ® Mass Counter. The cyclone attachment is at (A), and the inlet nozzle for the Royco ® counter is located just behind the cyclone (B).



scale 1" = 4'

1. Semi-clean transfer room (positive pressure to the outside exit).
2. Ceiling HEPA filter.
3. Floor exhaust with dampered control for variation in laminar flow over bench #4 and the positive pressure of the room.
4. Clean work table.
5. Bench for Jaffe-Wick preparation of filters.
6. Vented clean box for chloroform extraction of filters.
7. Laminar flow bench for filter sectioning and filtration.
8. Polyethylene sink.
9. Particle tac mat.

Figure 3.2-4 SAI's Trace Particle Clean Room.

cassettes inside the laminar flow bench of the clean room, using vacuum tweezers. Before sampling, an 8.0-μm pore size, 47-mm diameter Millipore® backing filter was placed under the Nuclepore® 0.2-μm pore size collection filter to insure even distribution of particles across the filter face.

After being loaded, each cassette was placed in a separate, clear plastic box (50mm x 80mm), which had been treated with a Zerostat® anti-static charge reducer. A secondary box specially constructed to reduce contamination and filter tipping was used to transport the filter boxes. Vibration during transportation was minimized by placing this secondary box containing the filters inside a larger box containing a plastic bag full of water and styrofoam pellets.

Filter cassette loading was done on a damp-wiped table in the mobile laboratory (Figure 3.2-5); the entire cyclone was disassembled and rinsed with Freon 113®. Cassettes and cyclone components were handled with polyethelyene gloves, reducing exposure time to contamination to that required to remove the sample from its box and transfer it to the head of the cyclone (approximately ten seconds).

Collection of Meteorological Data

Wind speed, wind direction and temperature were chart recorded by the Climatronics® weather station over each eight-hour sampling period. Relative humidity was recorded hourly since moisture can drastically affect particle counter measurements.

Although standard protocol calls for the location of wind measurements devices at least 30 ft above the ground, only at the King City, Sonora, Bakersfield, San Fernando Valley, and San Diego sites was this adhered to. San Jose and Napa are both park sites and each has trees taller than 50 ft; weather instruments were placed ten ft above ground at these sites. Although exact wind conditions were not obtainable, local effects on the air samplers

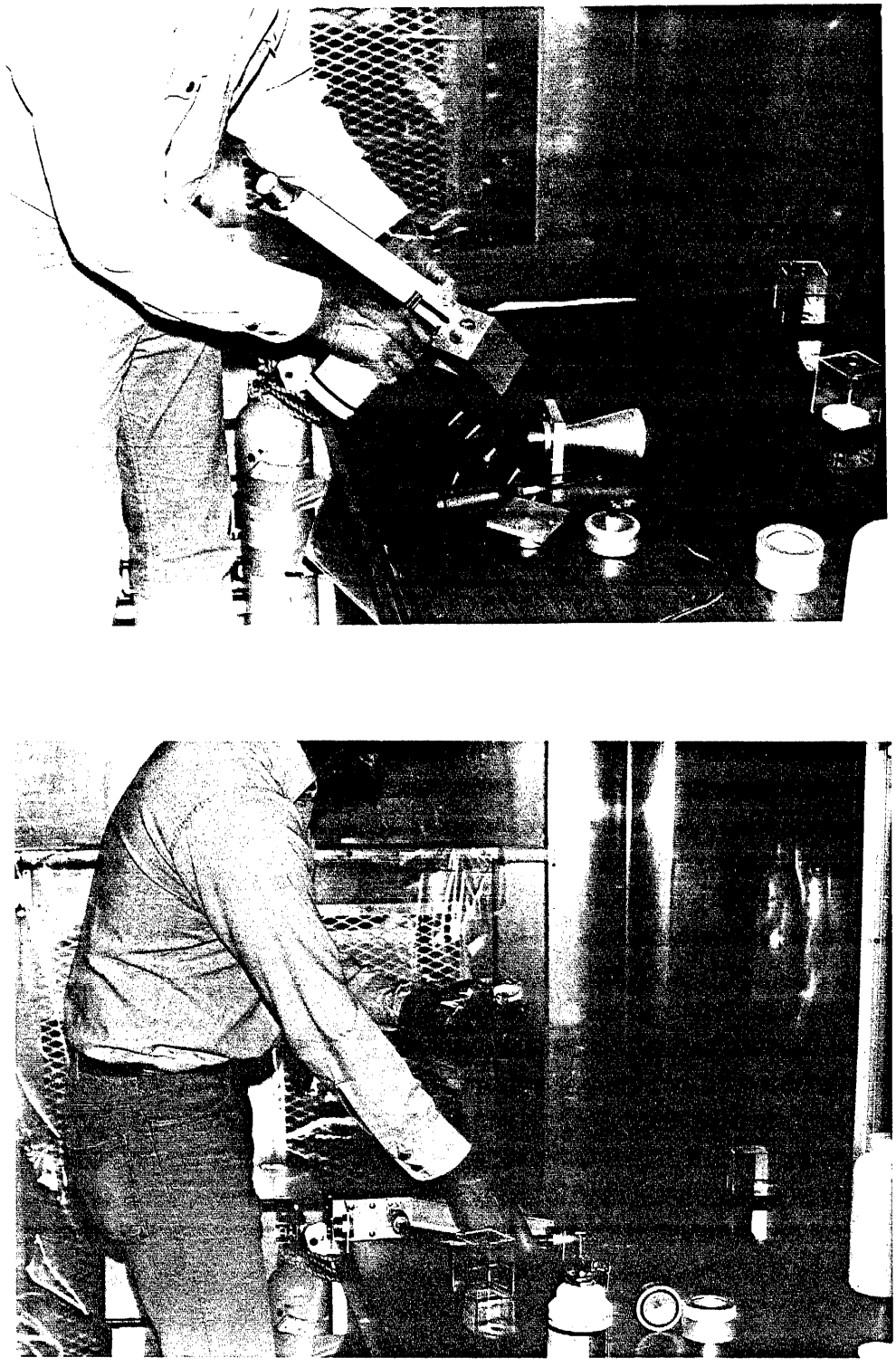


Figure 3.2-5. Cyclone Filter Assembly in SAI's Field Sampling Laboratory Van.

were measured at these sites, and general breeze direction above the tree tops was estimated. Weather conditions at the South Gate site were estimated due to problems in situating the weather tower. Because of the presence of numerous buildings it was not possible to accurately measure wind speed and direction at South Gate; these parameters were estimated. Temperature and relative humidity measurements were made by sling psychometer.

Air Sample Collection Procedures

Original sampling plans called for at least four four-hour samples at each site. Paired replicate samples were taken morning and afternoon at King City, San Jose, Napa, San Fernando Valley and Sonora. Century City, Bakersfield, South Gate and San Diego ordinarily have high particle concentration levels, so samples were collected at these locations over shorter time intervals to preclude overloading the filters. At these sites we were able to take five to nine samples per day. Sampling time was based on prior calibrations of filter loading as a function of suspended particle count level, by scanning electron microscopy.

Sample filtering was carefully done, as described earlier in this section, with plastic gloves worn to transfer filter cassettes to the precleaned cyclone assembly. The sampling pumps were operated at 15.5 L/min under a vacuum of six to seven inches of mercury. The pump and filter train were pre-tested to assure that there were no leaks in the six to seven-inch (mercury) vacuum range.

Collection of Particle Count Data

At the first four sites (King City, San Jose, Napa, Sonora), simultaneous particle count data were collected using the Royco® and the RAM® counters placed side by side on a 'cart'. The particle samplers were located three to four ft off the ground and never more than ten ft from one of the cyclone asbestos collection assemblies. The Royco® inlet was modified by

fitting a plastic bottle 'nozzle' having six 0.25-in diameter holes evenly spaced around it. This prevented contamination of the normal intake orifice in case the tubing fell or insects come in contact. To prevent extraneous material from contaminating the sampler, the face velocity at the 'nozzle' was reduced, resulting in loss of larger particles in the sampling line. Calibration of the inlet nozzle was accomplished by collecting 10 sets of alternating data both with and without the nozzle. The percent particles lost in each size range were calculated from the differential measurements. Laboratory calibrations determined actual loss for each size range of particles: 0% loss for 0.3 to 0.7-μm and 0.7 to 1.4-μm aerodynamic diameter ranges; 1.6% for 1.4 to 3.0 μm; 6.1% for 3.0 to 5.0 μm; 25.7% for >5.0 μm. These losses were accounted for in the calculation of size distribution.

During the simultaneous paired measurements, the inlet 'nozzle' of the Royco® was no more than one ft away from that of the RAM®. The integration time for the RAM® was 7.5 min; for the Royco®, 10 min. Both instruments were reset simultaneously to directly correlate each reading. By doing this, direct relationships between particle count and mass concentrations for all sites could be derived, even though the RAM® optical mass counter was unavailable for the other six sites.

3.3 Analytical Techniques

3.3.1 Sample Preparation Procedures

Once returned to the laboratory, the plastic filter cassettes were wiped clean with a damp, lint-free cloth and placed in clean room facilities. Everything relating to filter handling was cleaned with 0.2-μm pore size filtered water and blown dry with Freon® dusting spray. Direct handling of the filter cassettes was done with plastic gloves under a class 100 (fewer than 100 particles per cu. ft of air) laminar air flow. Particulate matter levels under the laminar air flow were maintained at less than 5 particles/cu. ft in the >0.3 μm diameter range; particulate matter in the clean room was kept at

less than 10 particles/cu. ft in the >0.7 μm size range. Mass levels measured by the RAM® counter in the center of the room were 1 $\mu g/m^3$.

Sectioning of Filters

Sectioning of Nuclepore® filters with the least disturbance to the membrane surface was a critical step in sample preparation. The Nuclepore® filter with 8.0-μm pore size Millipore backing filter was removed from the cassette and transferred to a 2-in x 2-in plexiglass plate. A new razor blade (cleaned with dusting spray) was slowly pressed on the filter pad using a downward vertical motion to cut the filter in half. The Nuclepore® filter section from each half filter was carefully slid off the Millipore® backing filter onto a clean piece of plexiglass. The filter was then tacked in place and a series of polyvinylchloride (PVC) cement beads were placed around the edges of each filter section. The tacked filters were allowed to dry under plastic petri dish covers. The plexiglass square containing the tacked filter section was placed in the bottom of a petri dish with a minimum clearance of 1.5 cm and fastened with double stick tape. One section was saved as an archive and for sub-sectioning for replicate analysis by the University of Washington. The other section was ready for carbon coating as required by the EPA method.

Carbon Coating Procedures

Carbon coating was done with a Denton® rotating stage carbon evaporator. The filters were carbon coated at 1 x 10^{-5} torr in short bursts with 30 to 40 nm of carbon. To minimize fiber dislodgement on the sampler filters, evacuation of the carbon coating chamber was performed slowly over a period of five minutes.

Modified Jaffe-Wick Grid Preparation

The filters were extracted using a modified Jaffe-Wick technique outlined in the provisional U.S. EPA methodology (EPA, 1978b). All petri dishes and utensils were precleaned and spray-dusted. The foam supports and filter paper sections were ultrasonically cleaned with three washes of analytical grade acetone. Although the provisional method calls for the use of screens to support Formvar® sample grids, Whatman® 42 filter papers were used because they produce more uniform grids. Another difference in the methodology was the use of 300-mesh instead of 200-mesh grids (300-mesh grids provide more support for the Formvar® grid layering, as well as more accurate tracking of particle location within each grid hole by electron microscopy).

A clean section of 0.25-in x 2-in x 2-in polyurethane foam with a 2-in x 2-in filter paper on top was placed in a 6-cm diameter petri dish. Approximately three to six 300-mesh sample grids were placed on top of the filter paper, Formvar® side up. Three square sections (4 mm x 4 mm) of the sample filter were excised with a clean razor blade and placed against the Formvar® side of the grid with the particle side facing against the grid. Each of the grids was then saturated with 5 to 8 µl of analytical grade chloroform by filling the petri dishes to a level that just covered the filter paper support, using a long-needle, 50-ml syringe. Each dish was transferred to a glass dessicator with a reservoir of chloroform below the support plate. The chloroform level in the petri dish was carefully raised to the top of the filter paper, the petri dish covered, the dessicator lid replaced and the filters allowed to dissolve for 24 hours. An outside light source just above the dessicator kept it at a temperature of about 26.7°C. After 24 hours, the chloroform from each dish was removed with a syringe and the grids were allowed to dry before being transferred to a grid storage box.

3.3.2 Sample Analysis Procedures

A JEOL 6C® transmission electron microscope (TEM), with a resolution of six angstroms and equipped with selected area electron diffraction (SAED), was used for all sample analyses. Calibration of instrument magnification was performed using a 21,400 lines/in carbon replicate standard against a scale etched on the fluorescent screen of the TEM.

The scale etched on the screen contained divisions of 1 cm, with a mm-division scale near the center. Both scales were set so that magnifications of 10,000X and 20,000X were accurate within 5%. All diameter measurements were done under the 10X viewing microscope on the TEM. At a magnification of 10,000X, 1 mm on the screen is equal to 0.1 μm; at 20,000X, 1 mm is equal to 0.05 μm. The counting magnification ranged from 15,000X to 20,000X.

Each lot of grids was calibrated in two ways. First optical calibration was performed on a Leitz Dialux 20® light microscope using a standard with divisions of 0.01 mm. Second, the area of the grid holes was checked by scanning electron microscopy (SEM; International Scientific Model III-A®). Calibration of scanning electron microscope magnification was performed using latex sphere standards of 2.02-μm and 4.0-μm diameters, respectively. Optical microscopy was not selected for analysis of the samples, since the optical technique is not able to measure fibers less than 5 μm in length.

3.4 Quantitation Techniques

Reporting of Particle Measurement Data

The count data from each sample were analyzed by a modified version of the computer program outlined in the U.S. EPA provisional methodology (EPA, 1978b). The reported data included fiber concentrations (by fiber type: chrysotile, amphibole, indeterminate, non-asbestos) as fibers/m^3 of air. Mass concentrations of asbestos (pg/m^3 air) were calculated, although these data

are subject to error accumulated from squaring particle radii in the computation*. In addition to the standard EPA reporting format, an additional category to distinguish chrysotile fibers in the occupational exposure size range (length >5.0 μm) has been provided.

In reporting data, values shown as zero are below detection limit (DL; a function of the total area of the filter scanned and the volume of air that is sampled). When only one fiber was found on the sample scanned, the value obtained was used to derive the detection limit. Samples having less than one fiber found during analysis were defined as being 'below detection limit' (<DL). All the samples analyzed were counted in an identical manner and had been collected at the same flow rate (15.5 L/min), therefore detection limit was a function only of the duration of sampling time. A graph of detection limit vs sampling time is presented in Figure 3.4-1. Since sampling times ranged from one to four hours, net detection limits ranged from 9100 to 2400 fibers/m^3 of air, respectively.

Reporting of Meteorological Parameters

The major meteorological parameters affecting particle concentration levels are summarized for each site in Section 4.0; tables describing meteorological conditions over the duration of each samples collection, are presented in the site-specific discussions. Meteorological parameters included temperature, relative humidity, wind direction and wind speed. Each site description also contains a graphic presentation of relative humidity, temperature, and wind speed trends based on one-half hour interval sampling throughout the collection day. The reporting of other pertinent variables such as visibility, sky cover and vegetation is covered in the general narrative summary of each site.

*Mass Concentration (pg/m^3) = particles/m^3 x particle density (pg/cm^3) x particle volume ($\pi r^2 \ell$/particle). ℓ = length, r = radius, pg = picogram.

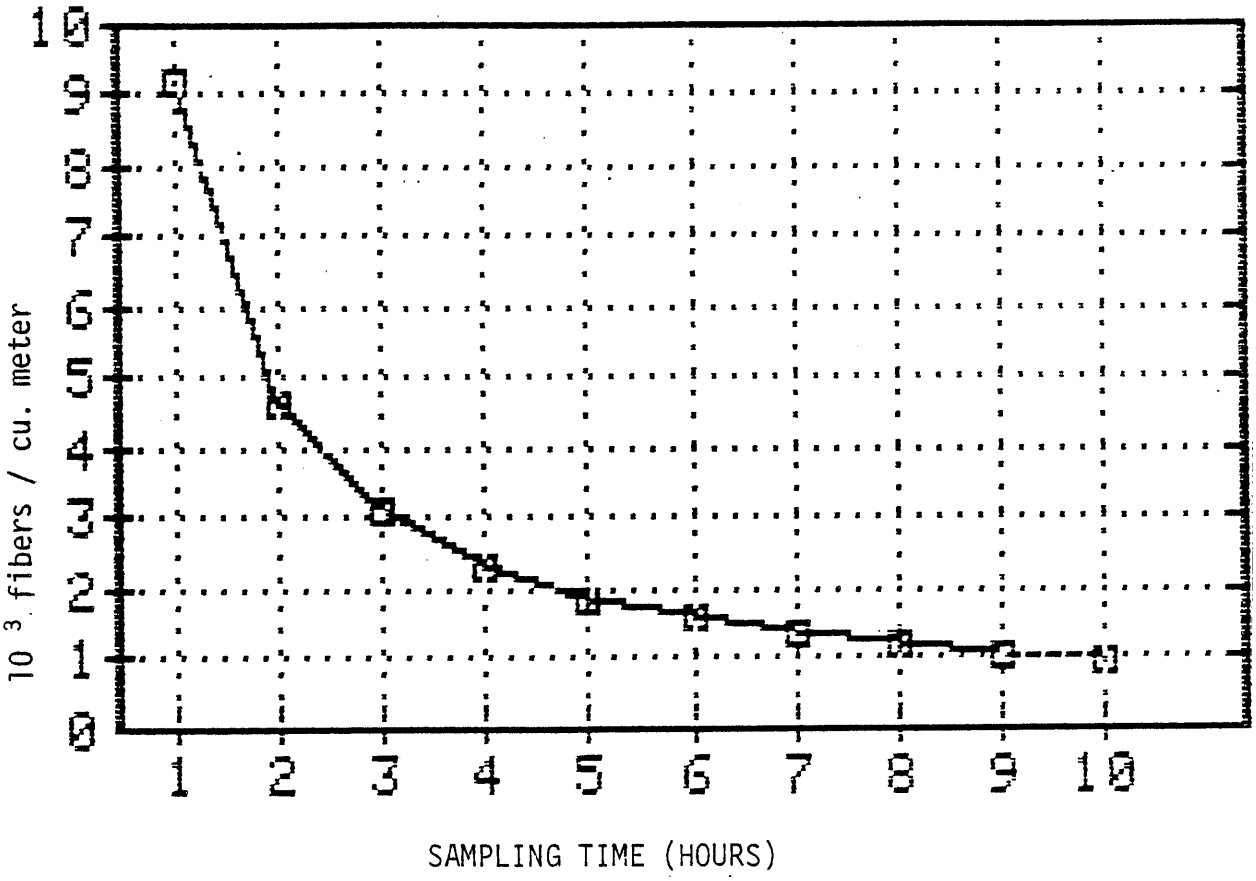


FIGURE 3.4-1. Relationship Between Minimum Asbestos Detection Limit vs Sampling Time

Measurement of Particle Counts in the Asbestos Size Range

Measurement of particle concentration levels representative of the 0.3μm to 0.7μm aerodynamic diameter range was most effectively made with the Rayco® particle counter to determine baseline and temporal variability of the airborne particle fraction most likely to contain asbestos. More than 95% of all fibers are contained in this particle size range. The Royco® counter sizes particles by their effective light reflection area, which is a function of both particle length and diameter; calibration is performed using a size series of latex spheres. For a particle to be counted as "0.7μm", it has to have an optically reflective area equivalent to a sphere with a 0.7-μm diameter. Direct measurements of airborne fibers by TEM indicate that 90% of all fibers collected were <1.0 μm long and <0.1 μm in cross-sectional diameter, equivalent to an aerodynamic diameter of 0.25 μm (Figure 3.4-2).

Note: The "aerodynamic diameter" relationship is based on normalization of the volume of a fiber to an equivalent sphere. An example of this calculation is:

Volume of fiber 1.0 μm in length and 0.1 μm in diameter:

$$V = \pi r^2 h = \pi(0.05)^2(1.0) = .0079\ \mu m^3$$

Diameter of an equivalent sphere:

$$V = \frac{4}{3}\pi r^3$$

$$\frac{4}{3}\pi r^3 = .0092\ \mu m^3$$

$$r = .123\ \mu m \quad (r = \text{radius})$$

$$D = .25\ \mu m \quad (D = \text{diameter})$$

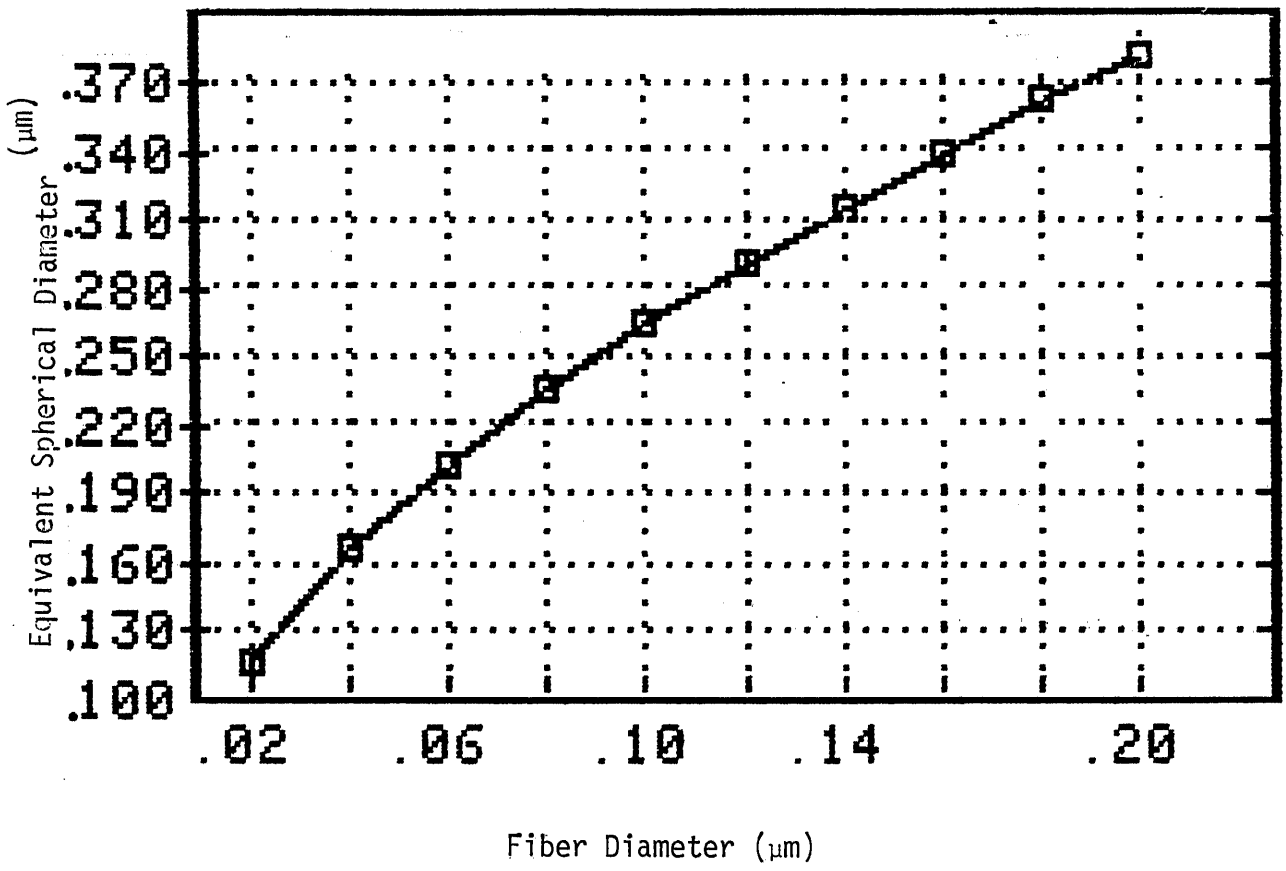


Figure 3.4-2 Relationship Between Fiber Diameter (for 1.0-μm long fiber) and Equivalent Spherical Diameter.

Figure 3.4-2 illustrates the effect of fiber diameter on the equivalent 'spherical' measurement (assuming the reflective area of measured particles are similar to the calibration spheres used by manufacturer) of a 1.0-μm long fiber by optical particle counter. Based on particle area only, a 1.0-μm long fiber must have a cross-sectional diameter of >0.14 μm to be detected by the Royco®. Although this approach is oversimplified, it illustrates the limitations of counting fibers by this instrument. Most airborne asbestos fibers are, as a result, below the detection limit of the particle counter. In this study the particle counter was not used to count asbestos fibers, but to establish suspended particle baselines from which to explain variations in asbestos levels during filter collection. From these relationships, asbestos emission levels can be 'normalized' for different sampling times and seasonal network particle count data. The optical particle counter approach was also important in determining the length of sampling time needed to obtain optimal filter loading for TEM analysis.

Calculation of Size Distribution

The Royco® particle counter data are displayed in a format containing total particle counts in five aerodynamic diameter ranges: >0.3 μm; >0.7 μm; >1.4 μm; >3.0 μm; and >5.0 μm. (The >0.3-μm range includes all particles from 0.3 μm to >5.0 μm; the >0.7-μm diameter range represents all particles from >0.7 μm to >5.0 μm; etc.) Determination of the number of particles in the sequential size ranges (>0.3 μm <0.7 μm; >0.7μm <1.4 μm; >1.4 μm <3.0 μm; >3.0 μm <5.0 μm) was done by subtracting the number of particles in each range from the number of particles in the next lower range. (Example: the number of particles in the >0.3-μm to <0.7-μm diameter range is equal to the number of particles >0.7 μm subtracted from the number of particles >0.3 μm.) The fraction of particles in each size range was then calculated by dividing by the total number of particles counted.

Determination of Mass Concentration

In an attempt to effectively relate network suspended particle data (TSP, FP, IP), and optical mass for all sites, conversions to optical mass from particle counts had to be arrived at for the sites where the RAM® mass counter was unavailable (Century City, the San Fernando Valley, Bakersfield, South Gate, and San Diego). It is recognized that the optical mass from the RAM® counter more closely represents the IP network data because of the size range measured (<20 μm). RAM® mass data are intended only as a relative comparison with TSP data, not as an absolute measure of these data. For three sites, San Jose, Sonora and Napa, linear regression and correlation analyses were performed between the total number of particles (>0.3μm aerodynamic diameter) using the Royco® counter and the total suspended mass data obtained from the RAM® counter (Figures 3.4-3, 3.4-4 and 3.4-5, respectively). The RAM® counter is only partially dependent upon the size of the particle, the counter is calibrated at the factory using standards, this calibration data was not available to SAI.

The San Jose linear regression analysis (Figure 3.4-3) was used to derive total mass concentration values for Century City, the San Fernando Valley, Bakersfield, South Gate and San Diego. All of these sites (according to electron microscopic observations) had substantial airborne particulate matter contributions from automobile emissions, similar to San Jose. The five sites covered by the San Jose regression analysis fit into the 'metropolitan' to 'suburban' categories as outlined in a recent comparative report on airborne particulate matter (Trijonis and Davis, 1981).

The data obtained from Napa and Sonora represent 'non-urban' conditions due to minimal vehicle exhaust and industrial emissions. Mass concentration values for King City (Union Carbide) were obtained from the regression analysis from Sonora (Figure 3.4-4). The RAM® counter was on-site at King City, but logistical constraints prevented the collection of sufficient data to derive mass concentrations directly.

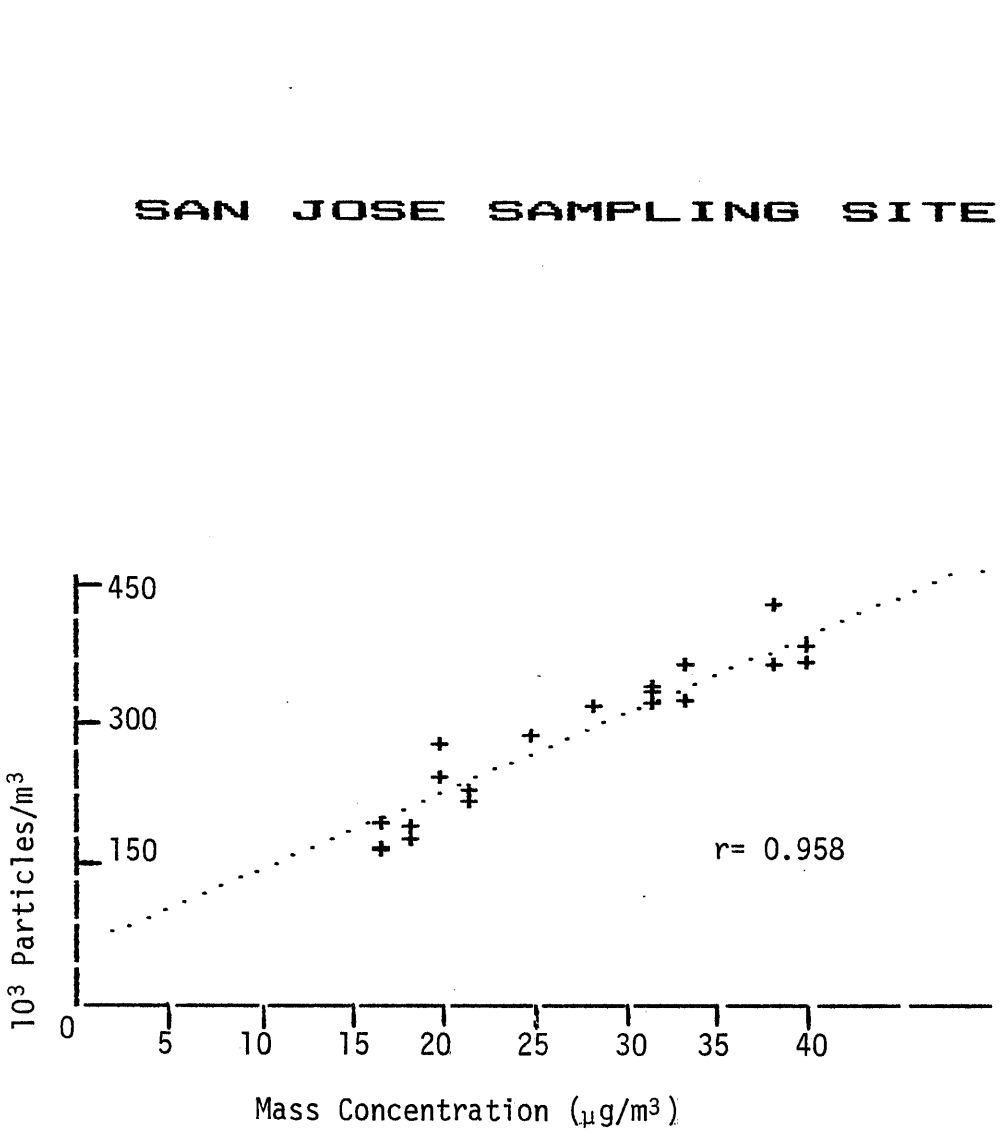


Figure 3.4-3. Linear Regression of Particle Counts (number/m^3) as a Function of Mass Concentration ($\mu g/m^3$), San Jose Site. Particle count data represent Royco® measurements for >0.3-μm diameter particles and mass concentration are from RAM® optical mass counter.

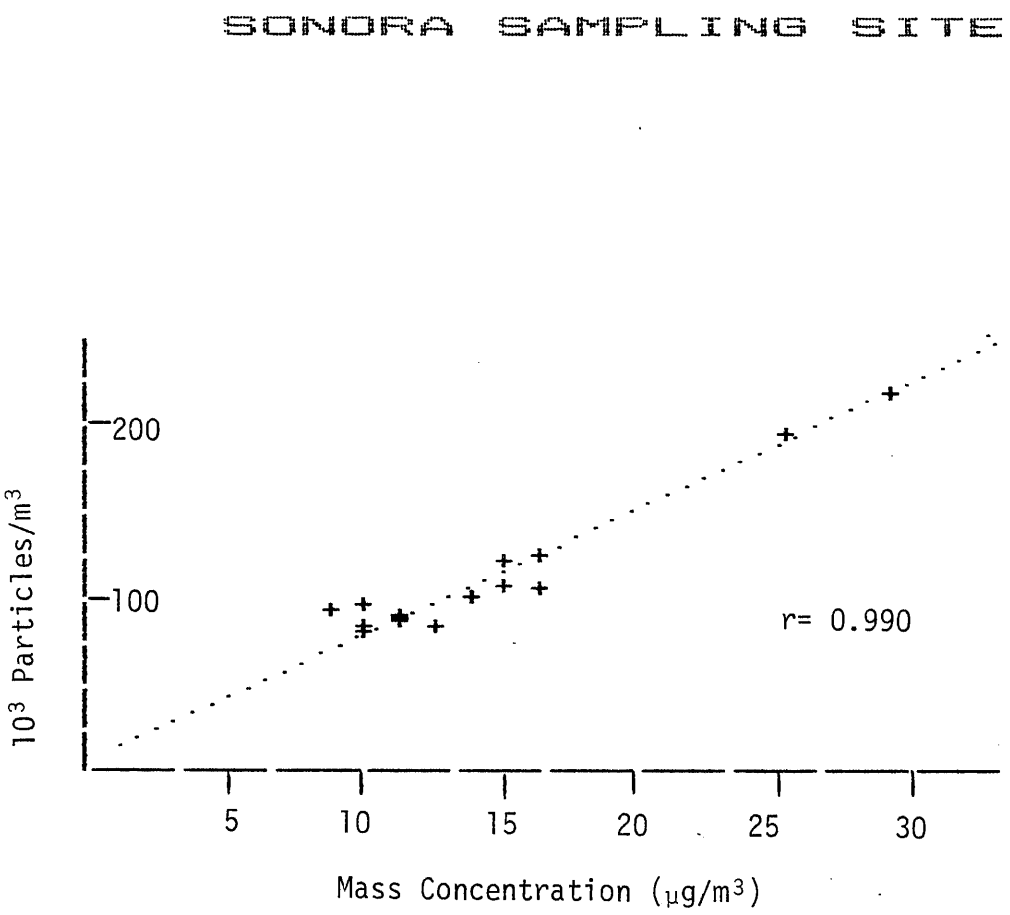


Figure 3.4-4. Linear Regression of Particle Counts (number/m^3) as a Function of Mass Concentration ($\mu g/m^3$), Sonora Site. Particle count data represent Royco® measurements for >0.3-μm diameter particles and mass concentration are from RAM ®optical mass counter.

The particle count vs mass concentration regression correlation generated for the Napa site (Figure 3.4-5) was used for deriving mass concentrations for that location only, and the Sonora data (Figure 3.4-4) were used for estimating values for the Stockton (Manville) site.

3.5 Quality Assurance

To fulfill the project's quality assurance requirements, the University of Washington Transmission Electron Microscopy Center was provided with replicate filter samples from different locations as part of an interlaboratory comparison. To insure proper handling in transit, the samples were carbon coated at SAI's laboratory and hand-carried to Seattle. The samples were analyzed according to the EPA provisional method and the data returned to SAI for computer reduction. In addition to a background control (the Napa site), sites selected for inter-comparison analyses (Table 3.5-1) were King City, Sonora, Century City, and San Diego. The Napa sample was done in duplicate by both laboratories to provide a measure of reproducibility.

The detection limit for TEM asbestos analysis in this study was approximately 2,400 fibers/m^3, the result of counting only one fiber in the filter area analyzed. The greatest difference between comparative samples was for the duplicated background control samples (Napa) done by the University of Washington. Although values for these two replicates are a factor of 11 apart (41,000 vs 3,600 fibers/m^3), the difference represents the counting of four fibers vs one fiber per total counting area, respectively. Differences between the two laboratorys' analytical results for the other replicate samples are in all cases less than the variation in the single duplicate analysis.

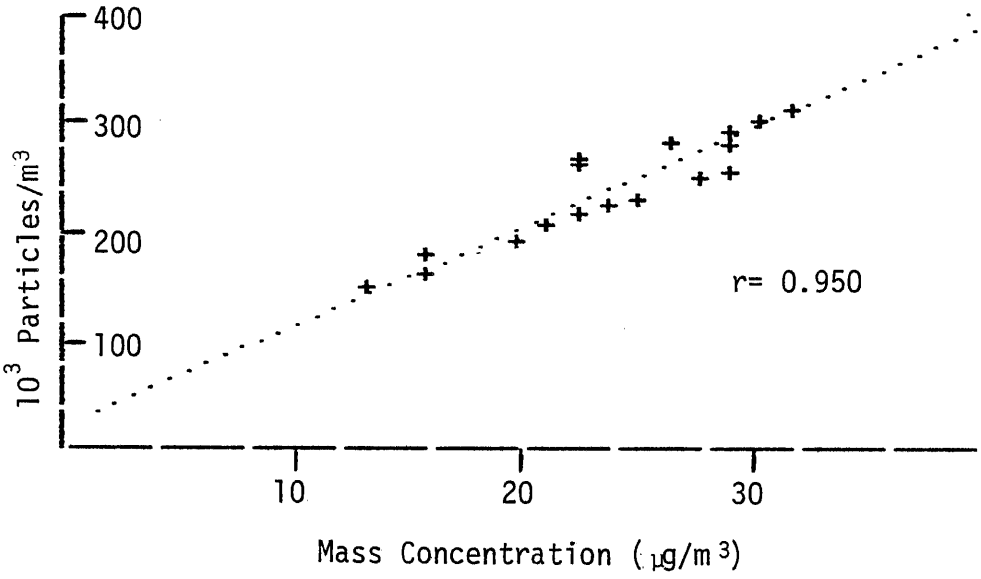


Figure 3.4-5. Linear Regression of Particle Counts (number/m^3) as a Function of Mass Concentration ($\mu g/m^3$), Napa Site. Particle count data represent Royco® measurements for >0.3-μm diameter particles and mass concentration are from RAM® optical mass counter.

Table 3.5-1 Interlaboratory Comparison of Asbestos Measurement by Transmission Electron Microscopy.

Sample	SAI TEC Laboratory		University of Washington	
	Chrysotile (fibers/m^3)	Amphibole (fibers/m^3)	Chrysotile (fibers/m^3)	Amphibole (fibers/m^3)
A-14 King City	9.4×10^3	<DL	1.5×10^4	3.6×10^3
A-24 Napa	4.7×10^3	7.1×10^3	4.1×10^4	7.2×10^3
	2.4×10^3	4.8×10^3	3.6×10^3	<DL
A-27 Sonora	2.4×10^3	2.4×10^3	2.1×10^4	1.2×10^4
A-100 Century City	1.5×10^4	<DL	1.7×10^4	2.1×10^3
A-202 San Diego	3.0×10^3	8.9×10^3	2.5×10^4	4.5×10^3

4.0 SITE SPECIFIC RESULTS

4.1 King City (Union Carbide Mill)

4.1.1 Site Location and Meteorology

The Union Carbide mill is an asbestos processing facility located approximately one mile south of King City in west-central California, 120 miles south of San Francisco and 34 miles east of the coast. The mill both refines and packages chrysotile asbestos ore. The ore is transported during the dry season by truck from mines at Coalinga and piled in an open air field next to the processing plant. The potential source of airborne asbestos consists of two points: one is the ore pile adjacent to the processing plant, and the other is the tailings pile approximately 1/8-mile east of the plant.

The Union Carbide mill is located in an area of low rolling hills with a normally predictable wind cycle. The typical "summer" pattern consists of calm winds in the early morning and high humidity due to the reverse flow of marine air; these conditions shift in the afternoon to northwest winds of generally 10 to 30 mph. Weather data for the sampling day (9/21/81) are shown in Figure 4.1-1. A light fog from the overnight flow of marine air dissipated around 10:00 a.m. The wind direction was consistently from the northwest and the wind increased gradually throughout the day, reaching 25 mph by 4:00 p.m. These winds were insufficient to cause visible resuspension of dust from the soil or from the ore and tailings piles. The relative humidity ranged from >90% in the early morning before sampling to a low of 32% in the afternoon when the wind velocities approached 25 mph and the temperature was approximately 30°C. After the fog dissipated in the early morning, the skies stayed clear for the rest of the day, with visibilities of 10 to 20 miles.

4.1.2 Asbestos Filter Sampling

Upwind and downwind samplers were located to measure any dust being resuspended from the ore and tailings piles. One pair of upwind-downwind

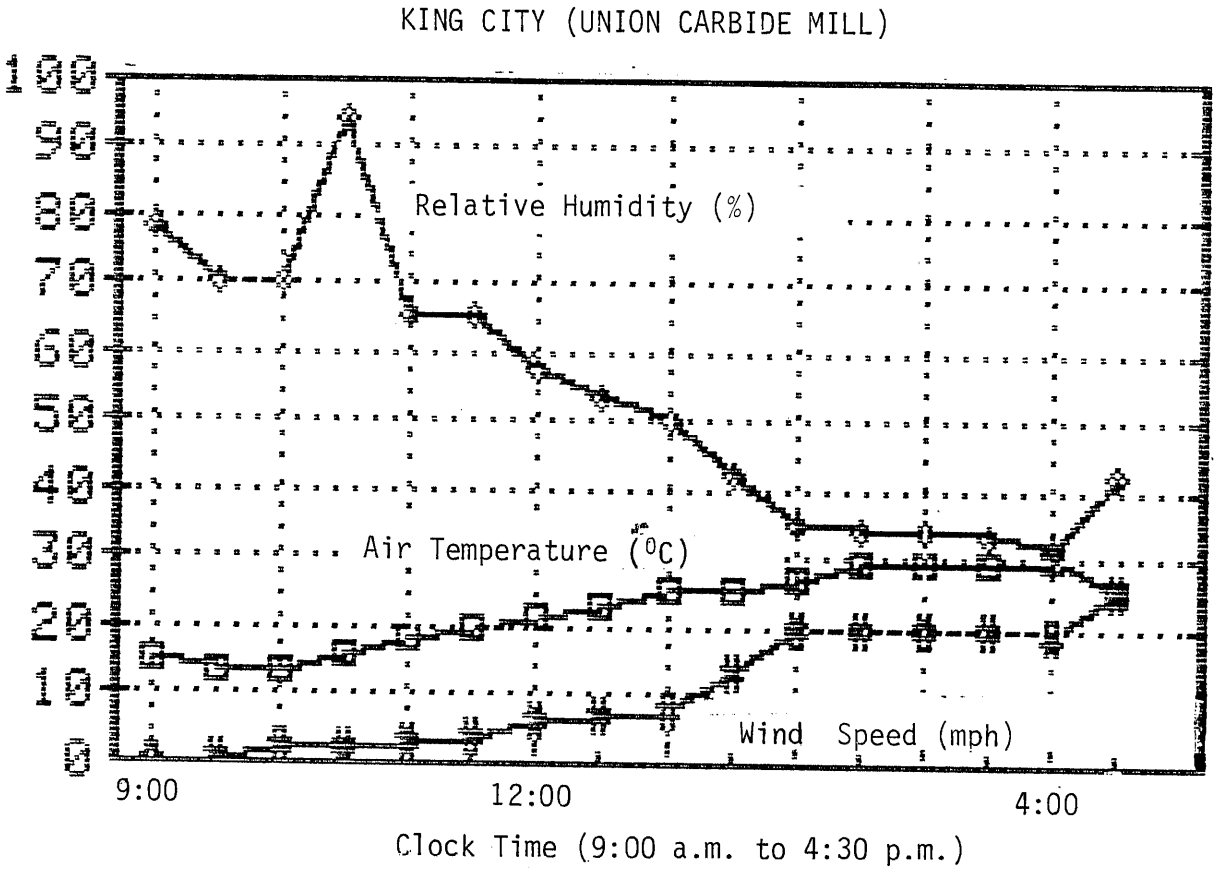


Figure 4.1-1. Meteorological Data Summary for King City. Based on one-half hour sampling intervals at the sampling location downwind from the Union Carbide mill site.

samples was taken in the morning in calm weather, and another pair was taken during the warmer, relatively windy afternoon. The analysis results from each filter sample collected are presented in Table 4.1-1.

The upwind site was located across U.S. Highway 101 on the north side of a farm house overlooking garlic fields. The sampling train was located near the edge of the cliff and placed six ft above the ground in order to minimize the effect of resuspended soil from immediately around the sampler. The upwind sample site is pictured in the top photo in Figure 4.1-2. The bottom photo is the view from the south side of the farm house looking across Highway 101 to the asbestos facility, showing the downwind sampler location relative to the ore pile. This site was located 0.25 miles directly downwind from the ore pile at the far boundary of the plant.

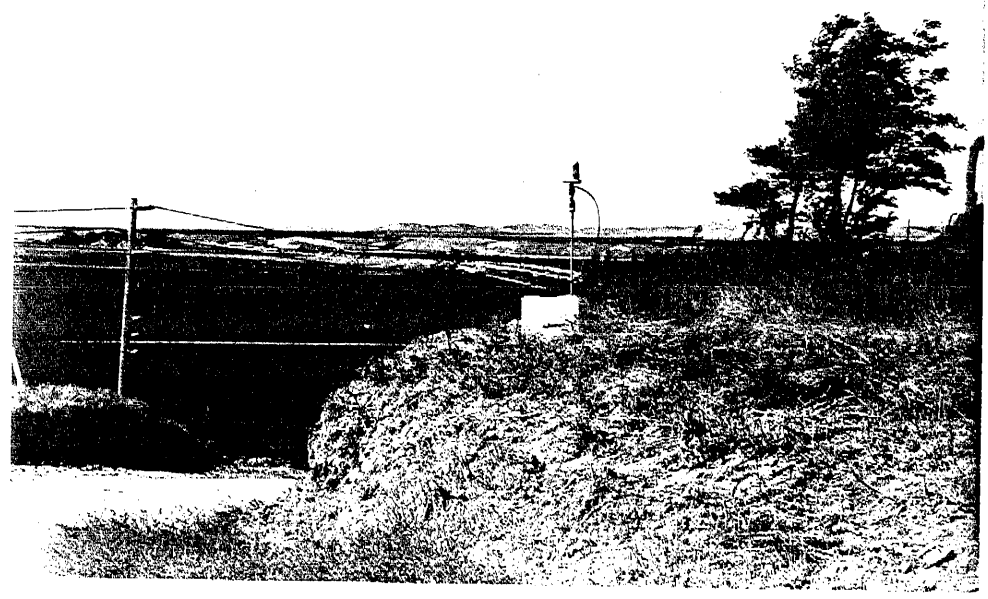
During the sampling period, activities potentially resuspending asbestos-laden material into the air included: the moderately high afternoon winds; the skip-loaders at the ore pile transferring ore into the plant; and tailings being transported to the waste pile east of the plant. The vehicular activity on the site and the transfer of raw asbestos material were likely to be the most important of these. However, since vehicular activity was minimal during sampling, 'worst case' conditions for asbestos emission were possibly missed.

4.1.3 Suspended Particle Monitoring

Figure 4.1-3 shows how upwind and downwind particulate mass concentrations varied throughout the sampling day at King City. These values were estimated by applying the regression equation of Royco® particle counts vs RAM® mass data determined for the Sonora site (Figure 3.4-4). Mass concentrations at the upwind location ranged from 42 $\mu g/m^3$ in the morning to approximately 14 $\mu g/m^3$ in the afternoon; the downwind levels ranged from 16 $\mu g/m^3$ to 20 $\mu g/m^3$. Differences between the early morning and afternoon mass concentrations at the upwind location are partially due to the noted presence of an

Table 4.1-1. Summary of Sampling Parameters and Analysis Results for King City (Union Carbide Mill Site).

Sample	Sampling Date	Site	Sampling Midpoint Time	Sampling Time (Minutes)	Sampling Vol. (liters)	Air Temp. (°C)	Rel. Hum. (%)	Wind Direction (°true)	Wind Speed (mph)	10^3 Particles/cu.ft. (>0.3μm <0.7μm)	Chrysotile Fibers/m^3	Amphibole Fibers/m^3
A-13	9/21/81	Upwind	9:46	238.9	3703	13	~70	360	0 - .5	70 ± 4	1.4×10^5	<DL
A-14	9/21/81	Downwind	11:07	240.0	3720	18	65	290	3.0	70 ± 4	9.4×10^3	<DL
A-15	9/21/81	Upwind	14:03	240.0	3720	27	35	340	8.0	260 ± 22	4.7×10^3	<DL
A-16	9/21/81	Downwind	15:45	239.0	3704.5	30	~32	340	19.0	65 ± 2	2.4×10^3 (DL)	<DL



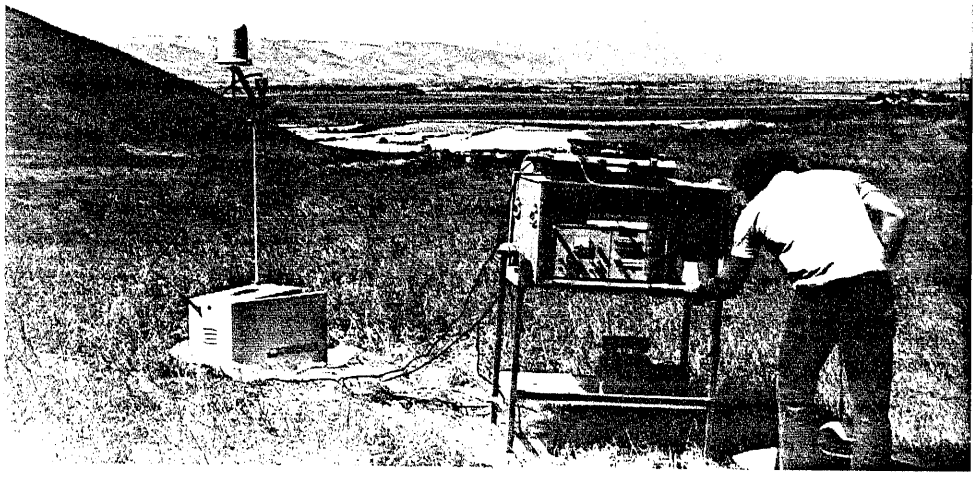


Figure 4.1-2. King City (Union Carbide Mill) Site Description.

Top Photo: The upwind sampler location; view is north. The predominant afternoon wind blows from left to right in the photo.

Bottom Photo: The downwind sampler location at the southern property boundary, directly downwind from the ore pile.

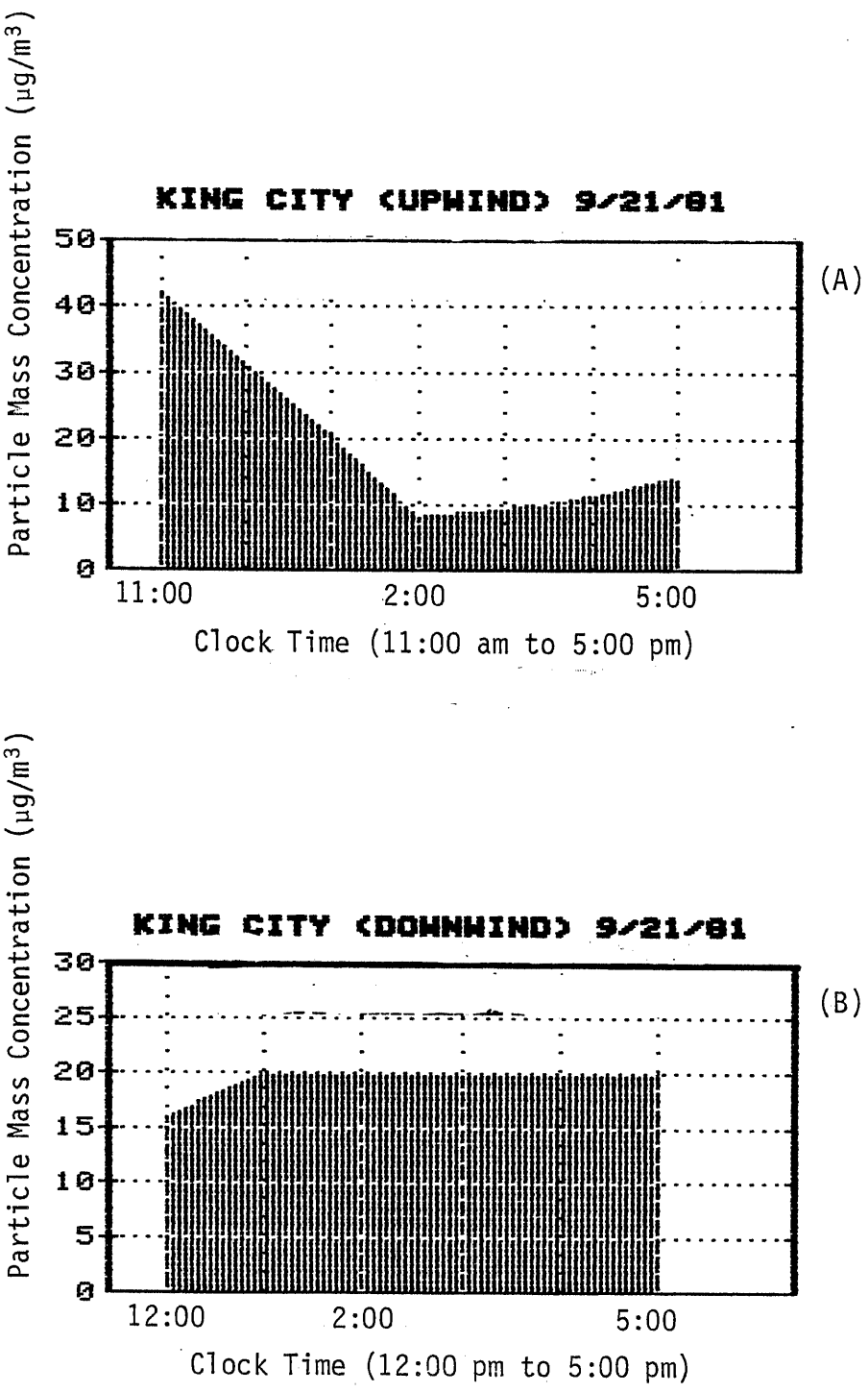


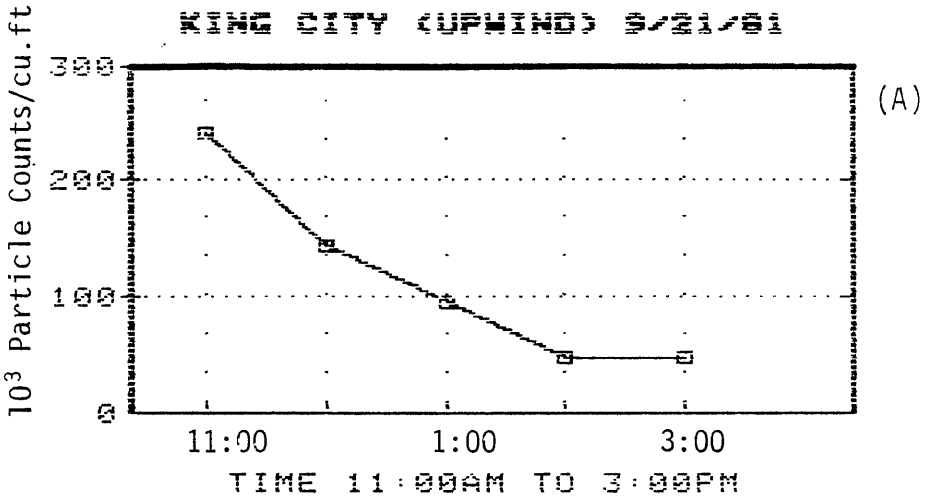
Figure 4.1-3. Optically-Derived Particle Mass Concentration Trends with Time at the King City Sites UPWIND (A) and DOWNWIND (B) from the Union Carbide Mill. Data were collected at one-hour intervals using the Royco ® Particle Counter and Mass was derived based on the Sonora Regression Analysis.

early morning fog, which produced water droplets that contributed to both mass and particle detectability. Mass concentrations at the downwind location were less variable due to a later starting time which missed much of the fog's effects. However, comparisons of the upwind and downwind data show definite differences in the mass concentrations from 2:00 a.m. to 5:00 p.m. Most likely, the difference between 20 $\mu g/m^3$ at the downwind site and the approximately 10 $\mu g/m^3$ at the upwind site was due to the placement of the downwind sampler on a dry dirt field full of dead weeds. Forming an uneven carpet approximately one ft thick, the dirt field served as a significant potential source of airborne particulate matter under any physical disturbance.

Concentrations of particles in the <0.7-μm aerodynamic diameter range for the upwind and downwind sites are graphed in Figure 4.1-4. The trends in particle counts followed the same pattern as the mass concentrations. The afternoon levels were approximately 50,000 particles/cu. ft for the upwind site and 70,000 particles/cu. ft for the downwind site. Increasing wind changed the size distribution of particles at both sites. Figure 4.1-5 depicts the upwind and downwind particle size distributions in the morning and afternoon. The key change in particle distribution was a greater proportion of large size particles due to higher afternoon winds. This shift in size distribution, coupled with a decrease in particle counts in the <0.7-μm aerodynamic diameter range in the afternoon, indicates that the local winds, at a velocity of 20 mph, were not resuspending particles, but were purging the area of any locally produced particles (including asbestos).

4.1.4 Asbestos Levels

The results of the transmission electron microscopic (TEM) analyses are presented in detail in Volume II, and the summarized results, along with sampling and meteorological information, are in Table 4.1-1. Unexpectedly, the highest value measured occurred at the upwind site in the morning. The levels of chrysotile were 10 to 100 times higher at the upwind site (140,000



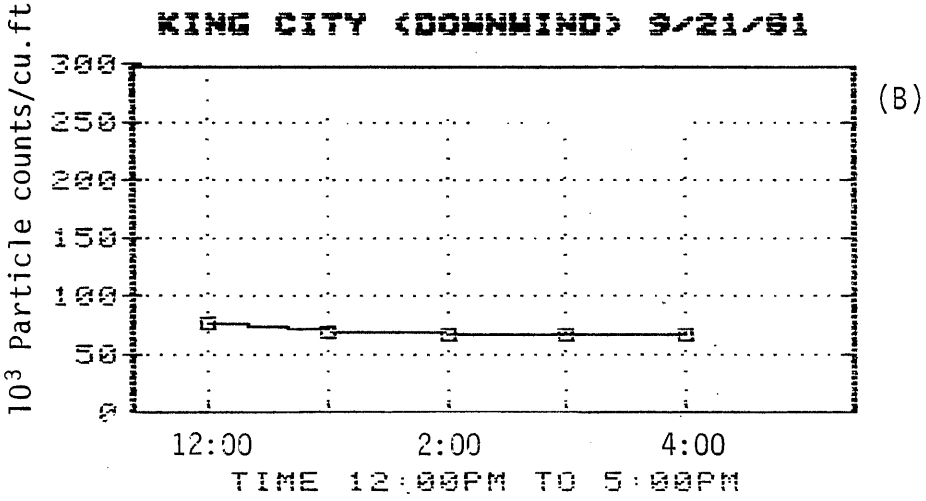
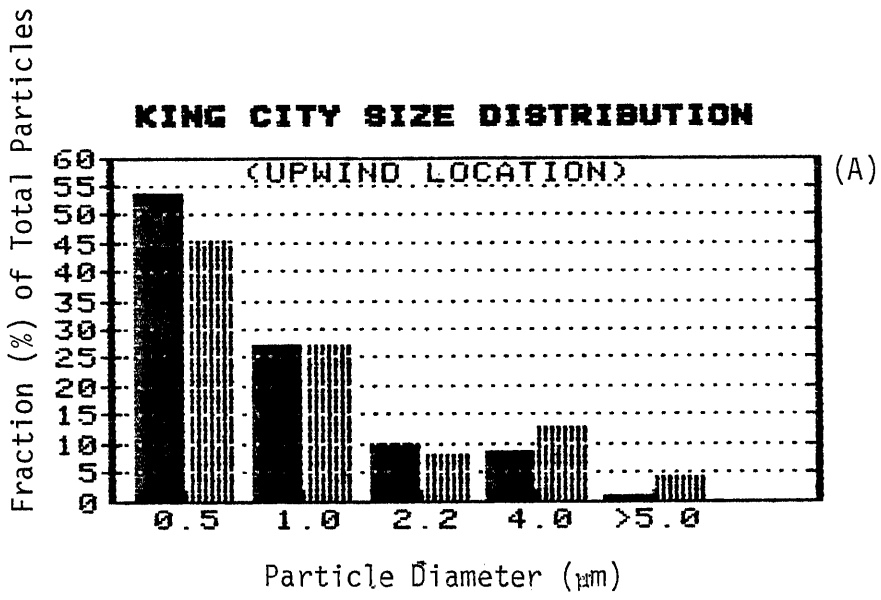


Figure 4.1-4. Optically-Derived Particle Count Trends with Time at the King City Sites UPWIND (A) and DOWNWIND (B) from the Union Carbide Mill. Data were collected at one-hour intervals using the Royco ® Optical Particle Counter for aerodynamic diameters <0.7 μm.



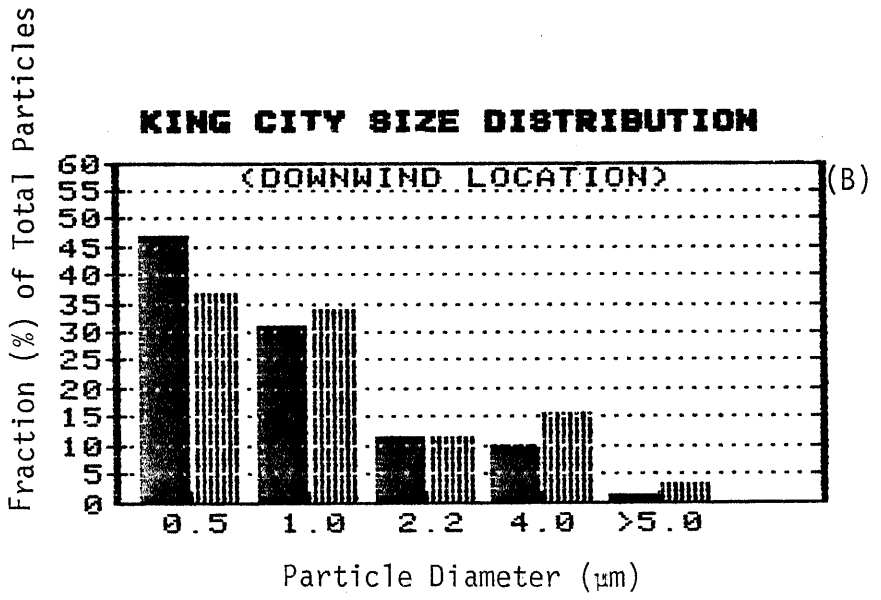


Figure 4.1-5. Particle Size Distributions at the King City UPWIND (A) and DOWNWIND (B) Sampling Sites.

fibers/m^3) than they were at the highest morning level (9,400 fibers/m^3) at the downwind site. No fibers longer than 5.0 μm were detected.

In addition to measuring ambient atmospheric asbestos, we considered the possibility that asbestos settles onto the soil in the vicinity of the plant. Accordingly, a soil sample was taken from both the upwind and downwind sites adjacent to each cyclone sampler. Since there is no formal procedure for analyzing asbestos in soil, we used a modified procedure based on standard sedimentological methods. The main impetus for measuring asbestos in soil is its potential as a source of airborne particulate matter as a result of aerodynamic entrainment under nominal wind conditions. Crushing or grinding the soil would not provide an accurate picture of potential resuspension of asbestos fibers and was therefore not used in determining asbestos concentrations. The samples were first shaken for five minutes by hand through a 120-mesh sieve (125-μm diameter pores), and each fraction weighed. The <125-μm size fraction was analyzed, since the >125-μm size fraction was assumed to be too large to undergo resuspension.

The <125-μm size fraction was placed in a plastic, round bottom 15-ml test tube with 10 ml of deionized 0.2-μm pore-size filtered water. The sample was shaken for two minutes by hand and transferred to a 2-m Emery column to separate out the larger particles. (An Emery settling column is a 2-m high, 25-mm diameter glass pipette used for routine separation of sand and silt sand size particles.) The settling rate of a particle is a direct function of its aerodynamic diameter, the viscosity of the settling medium and the difference between the particle density and the density of the settling medium which, in this case, was water. The Stokes settling equation is based on spherical particles and is given as:

$$V = \frac{2\ ar^2\ (d1-d2)}{9n}$$

V = settling velocity cm/sec

a = acceleration due to gravity

r = radius of sphere (cm)
d1 = density of sphere (g/cc)
d2 = density of settling medium (g/cc)
n = viscosity of settling medium (cp)

Since most particles (especially fibers) are not spherical, settling is also a function of individual sphericity, defined as:

$$Sp = \sqrt[3]{\frac{S^2}{\ell I}}$$

Sp = sphericity
ℓ = length
I = intermediate dimension
S = short dimension

A particle with a sphericity of 0.5 settles half as fast as one of an equivalent diameter. By definition, a fiber must have a length-to-width aspect ratio of 3:1, meaning that the shortest fibers will have a sphericity no greater than 0.69. The typical length-to-width aspect ratio for asbestos in ambient air is approximately 10:1 (Campbell, 1978), the effective sphericity for fibers in this range being approximately 0.45. The corrected settling rate for fibers is, therefore, the sphericity times the Stokes settling velocity:

Cv = Sp x V = corrected velocity
S_p = sphericity
V = velocity (cm/sec)

After the sample had settled for 100 minutes, the coarse fraction was drained through the Emery column stop-cock and discarded. The remaining 800 ml of solution were drained into a clean 1-L bottle for sample preparation. The settling time corresponds to the Wentworth size scale cutoff between 'very fine sand' and 'silt' (62-μm particle diameter). A more refined analysis might require the separation at the 20-μm diameter point, necessitating 16

might require the separation at the 20-μm diameter point, necessitating 16 hours of settling in an Emery column. Although sample preparation time would be dramatically increased, so would the asbestos detection limit in the soil sample.

The one liter collection bottle with sample was shaken for approximately one minute, and a 1-ml aliquot was transferred with 10 ml of 0.1-μm filtered water to a 25-mm diameter filter funnel having a 0.2-μm pore size Nuclepore collection filter and a 0.4-μm pore size Millipore backing filter. The filtering dilution at this point was 0.0012. After filtering, the sample was weighed then prepared for electron microscopy as described for airborne particles. Details of the results appear in Volume II; in summary, for chrysotile asbestos:

Sediment Analysis

Sample	Fibers/g (total)	Fibers/g (>5.0 μm)	Mean Length
Upwind	9,600,000	310,000	1.7 μm
Downwind	29,000,000	2,900,000	2.4 μm

As we expected, the downwind concentrations of total asbestos (29,000,000 fibers/g) were higher than the upwind levels (9,600,000 fibers/g). This should be the case because the downwind samplers were located within the confines of the asbestos mill property lines and transportation routes for transportation of asbestos ore. The mean fiber length was also slightly higher. The magnitude of the sediment levels at the upwind location was unexpectedly, only three times lower than the downwind location. Because upwind sediment samples taken at the air sampler were located one-half mile upwind from the plant facility, high asbestos levels in the soil indicate that there is a potential for asbestos transport to the upwind side of the plant under certain meteorological conditions.

4.1.5 Analysis Summary

Data for the King City site reflect complex interactions occurring between local meteorology and the asbestos mill operational parameters. On a typical day, the afternoon winds suspend fibers from the Union Carbide mill, however airborne concentrations remain relatively low as wind flow carries away and rapidly dilutes asbestos fibers to below detectable concentration limits. Factors which can alter this situation include unusual on-site vehicle activity and unusually high wind conditions. These conditions were not observed during our visit to the mill.

Higher levels of suspended particles in the upwind and downwind morning samples result from high humidity combined with very calm air. The absence of wind late at night and early in the morning prevented airborne fibers from being carried away from the plant area, setting the stage for particulate matter to form condensation nuclei in the morning fog. The early morning asbestos level of 140,000 fibers/m^3 (Table 4.1-1) was representative of a 'best case' situation. Although we did not monitor under conditions of visible dust resuspension, it is expected that in such a case asbestos levels would definitely exceed those observed in this study. It could be concluded that asbestos levels above 1,500,000 fibers/m^3 could be found in the vicinity of either the upwind or downwind locations. This would be expected to occur under the combined conditions of high dust resuspension from mechanical activity and low wind speeds.

Given these observations, the downwind area of San Lucas is likely to have elevated levels of asbestos predominantly in the afternoon and evening, and King City is likely to have elevated asbestos levels at late night and early in the morning.

4.2 San Jose (St. James Park)

4.2.1 Site Location and Meteorology

The San Jose site is an urban point source within the cluster of industrial asbestos users outlined in Section 3.0. It is also an area of high population. St. James Park is located at the intersection of North Fourth Street and St. James Street in downtown San Jose. The site is one block from the CARB monitoring station on Fourth Street. Parks were selected for monitoring sites because they provide a buffer from direct traffic.

The weather on the sampling day (9/22/81) was sunny with the relative humidity decreasing from approximately 80% in the early morning to less than 30% in the late afternoon (Figure 4.2-1). The high relative humidity in the morning was contributed to by the early morning watering of park lawns. The temperature ranged from 15° C to 27° C and the winds were no greater than two mph from north-northwest during the entire sampling period. The skies were clear with visibility approximately ten miles. The weather tower was not used at this site because nearby trees, which were higher than 50 ft, interfered with the wind pattern. The sensors were placed in the courtyard of the park at the same level as the particle counter and the cyclone filters. The cyclones were put on a bench seven ft above a concrete patio (Figure 4.2-2). The courtyard was separated from the rest of the park by a five-ft wooden fence.

4.2.2 Asbestos Filter Sampling

Filter sampling was conducted using two paired, four-hour samples in the morning and two paired, four-hour samples in the afternoon. The cyclones were approximately six ft apart to ensure a good combined sample average. Pairing the sample collection was thought to be necessary in areas suspected of asbestos concentrations at the detection limit of TEM counting.

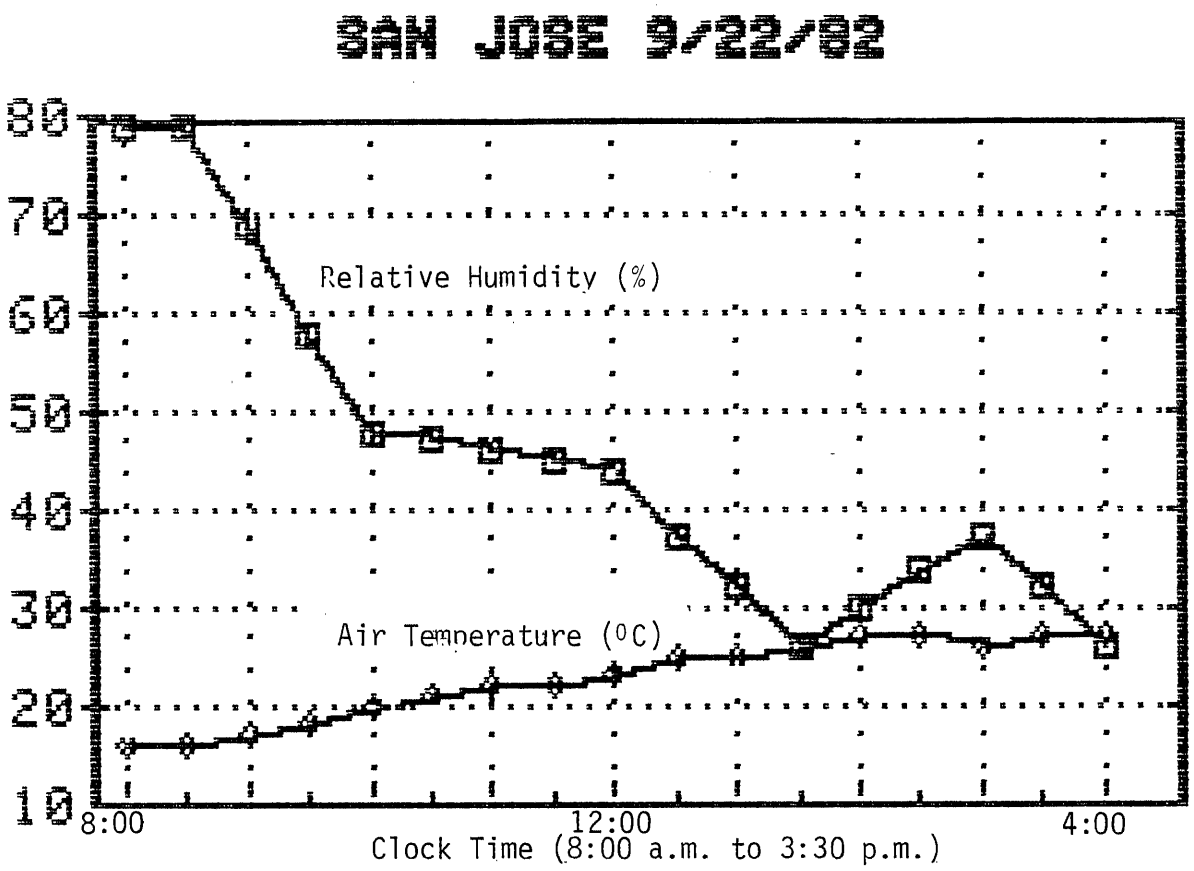


Figure 4.2-1. Meteorological Data Summary for San Jose. Based on one-half hour sampling intervals.

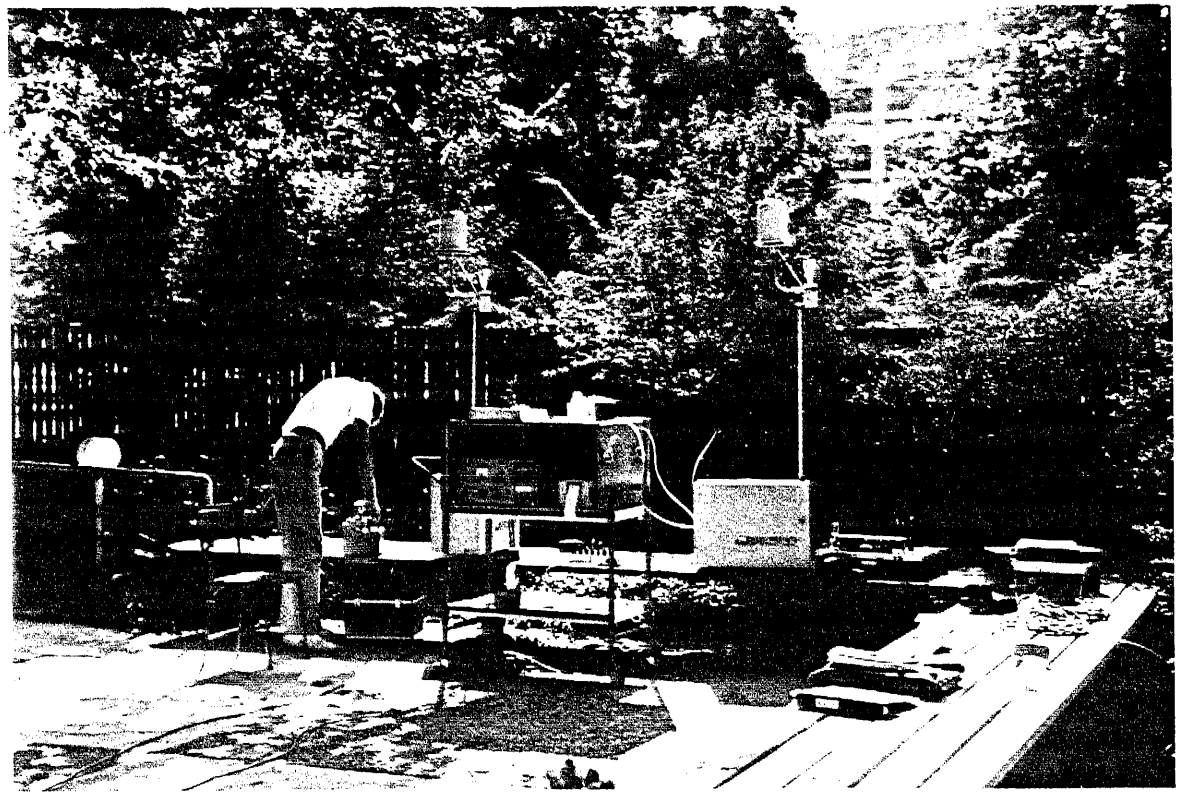


Figure 4.2-2. San Jose Sampling Site (St. James Park).
View north from the inner courtyard of the park.

4.2.3 Suspended Particle Monitoring

Figure 4.2-3 shows the trend in total particulate mass concentration during the sampling day. The values were estimated from a linear regression analysis of Royco® particle counts and RAM® mass data. Mass concentrations ranged from 100 $\mu g/m^3$ in the early morning to approximately 20 $\mu g/m^3$ in the afternoon. The decreasing trend in the particle count and mass levels was real and not affected by decreases in relative humidity, which occurred after approximately 9:00 a.m. Numbers of particles/cu. ft in the <0.7-μm aerodynamic diameter range are graphed in Figure 4.2-4, showing particle counts ranging from approximately 500,000/cu. ft in the morning and gradually decreasing to 100,000 particles/cu. ft in the late afternoon. Local bus traffic 100-m east and west of the samplers probably contributed to the observed particle count levels. Information on particle size distribution is presented in Figure 4.2-5.

4.2.4 Asbestos Levels

The transmission electron microscope results (Table 4.2-1) indicated amphibole asbestos levels approach the minimum detection limit with no meaningful morning-to-afternoon pattern. The chrysotile levels in the morning hours (21,000 fibers/m^3 and 14,000 fibers/m^3) represented marginal elevations over the afternoon concentration. Such levels in the 10,000 fibers/m^3 range represent only slight elevation above background. No fibers longer than 5.0 μm were found.

4.2.5 Analysis Summary

The low levels of both chrysotile and amphibole asbestos indicates that proximity to a relatively large number of industrial and commercial asbestos facilities does not necessarily imply high airborne asbestos concentrations. The population in this area was probably not exposed to any significant asbestos levels, even though particulate matter concentrations increased by an order of magnitude.

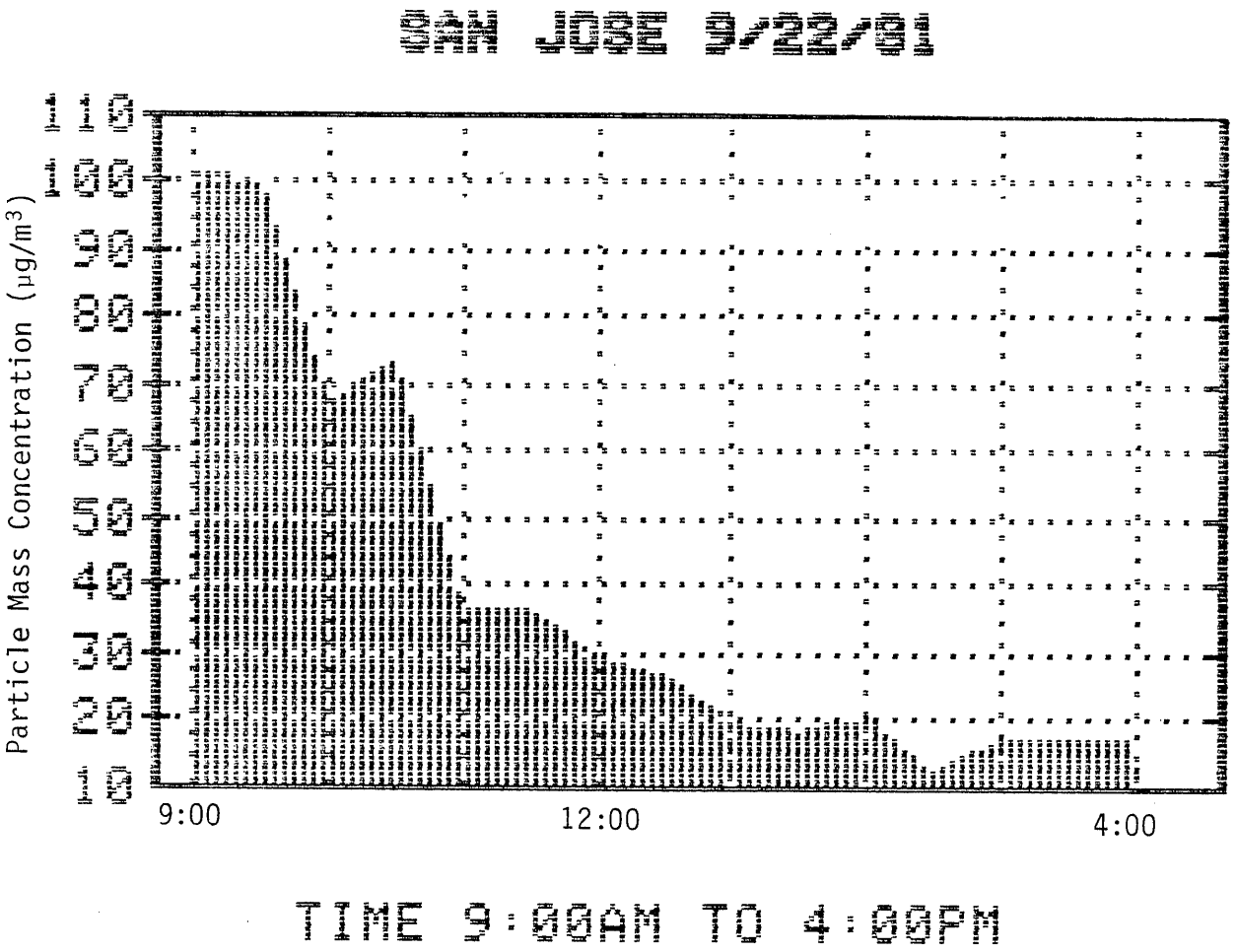


Figure 4.2-3. Optically-Derived Particle Mass Concentration Trend with Time at the San Jose Site. Mass data were collected at one-half hour intervals using the RAM® Optical Mass Counter.

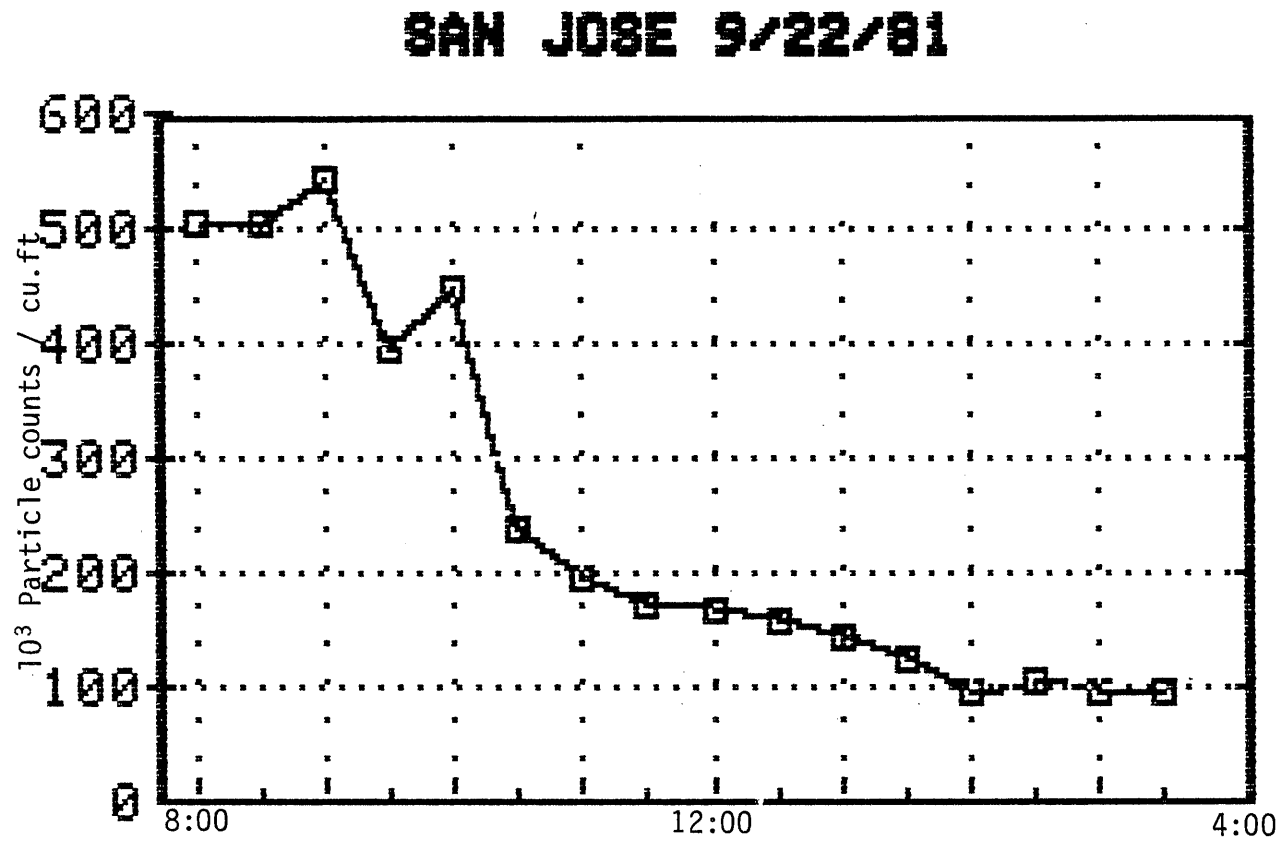


Figure 4.2-4. Optically-Derived Particle Count Trend with Time at the San Jose Site. Data were collected at one-half hour intervals using the Royco ® Optical Particle Counter for aerodynamic diameters <0.7 μm.

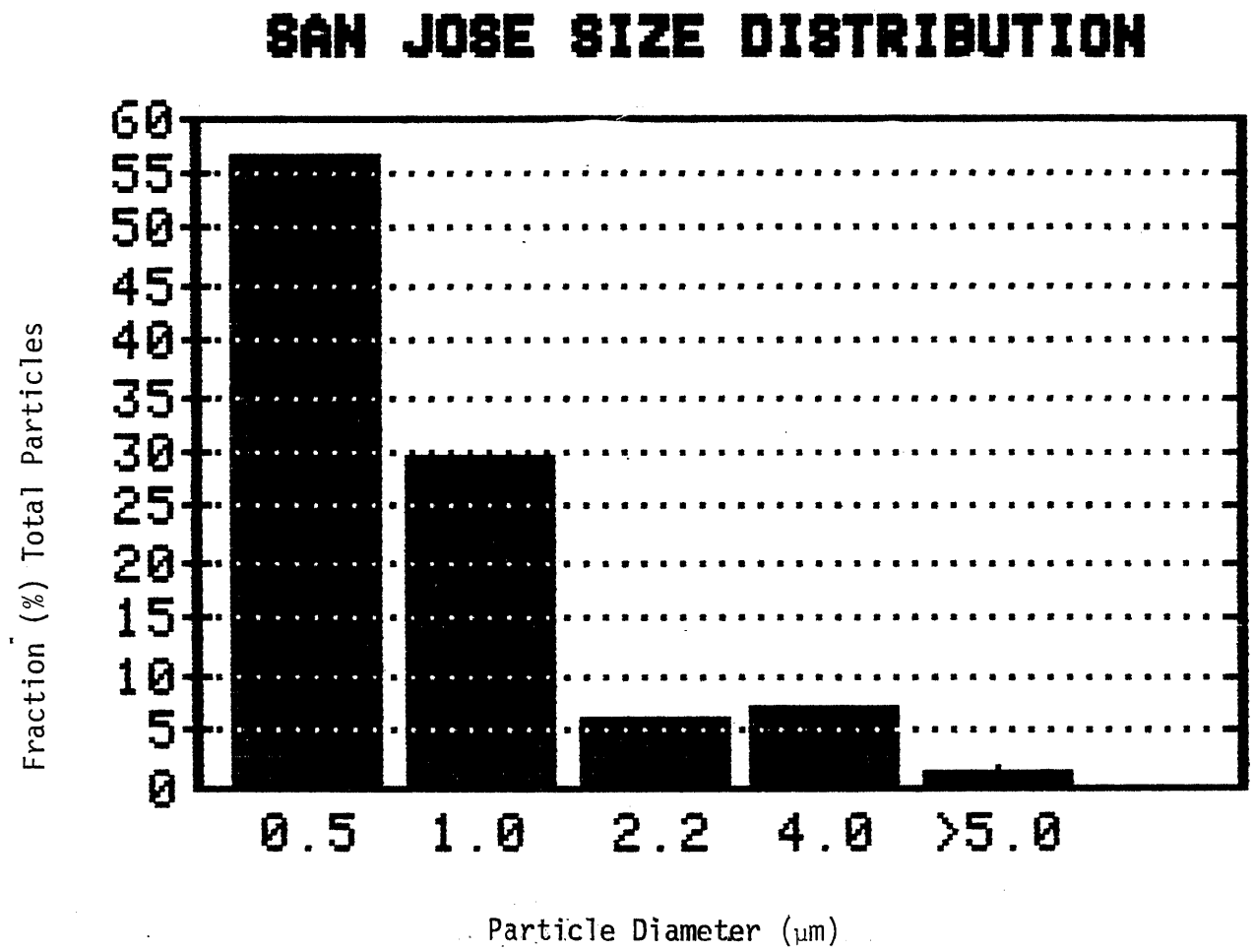


Figure 4.2-5. Particle Size Distribution at the San Jose Site. Data represent eight-hour averages.

Table 4.2-1. San Jose Summary of Sampling Parameters and Analysis Results.

Sample	Sampling Date	Site	Sampling Midpoint Time	Sampling Time (Minutes)	Sampling Vol. (liters)	Air Temp. (°C)	Rel. Hum. (%)	Wind Direction (°true)	Wind Speed (mph)	Particles/cu.ft. x 10^3 > 0.3 < 0.7μm	Chrysotile Fibers/m^3	Amphibole Fibers/m^3
A-17	9/22/81	Sampler 2	10:15	240	3720	21	447	330	1	280 ± 150	2.1×10^4	2.9×10^3
A-18	9/22/81	Sampler 1	10:31	241.1	3737.1	21	447	330	1	330 ± 89	1.4×10^4	9.4×10^3
A-19	9/22/81	Sampler 2	14:30	240	3720	27	37	330	1.5	120 ± 31	9.4×10^3 (DL)	2.4×10^3 (DL)
A-20	9/22/81	Sampler 1	14:43	240	3720	27	37	330	2.0	120 ± 31	1.4×10^4	7.1×10^3