# Reconciling Fugitive Dust Emission Inventories with Ambient Measurements

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## ABSTRACT

The actual impact of fugitive dust emissions on ambient air quality and associated visibility impairment at downwind receptor sites is significantly less than estimates based on fugitive dust emission rates measured at the source. This is due to deposition losses of particles caused by impaction with vertical surfaces (e.g., vegetation) and gravitational losses to the ground. This paper addresses the transportable fraction for fugitive dust emissions on an urban scale as well as a neighborhood scale based on an assessment of PM10 measurements from the California Regional Particulate Air Quality Study (CRPAQS) conducted in the San Joaquin Valley (SJV) in 2000. In addition estimates of the contribution of fugitive dust sources to ambient PM10 concentrations are compared to fugitive dust contribution estimates based on a PM10 emission inventory that accounts for both primary PM10 emission sources and emissions of gas phase precursors of secondary particulate material. The ratio of fugitive dust in the PM2.5 and PM10 size fractions for sites in the SJV are approximately a factor of two to three lower than that published by EPA for different fugitive dust source categories. This is due to the fact that the relative abundance of the two major elements associated with geological material, silicon and aluminum, are approximately a factor of two to three lower in the PM2.5 size fraction compared to the PM10 size fraction.

## INTRODUCTION

Source apportionment studies indicate that geological fugitive dust material contributes approximately half of the PM10 concentrations in many urban areas, whereas emissions inventories show area sources of geological material contributing as much as 90% of primary PM10 emissions. In the past researchers have entertained the idea that dividing fugitive dust emissions by a factor of four would eliminate the discrepancy between emission estimates and ambient measurements of fugitive dust. However, it is highly unlikely that this "factor of four" is applicable universally for different land cover categories and different atmospheric conditions. To reconcile the discrepancies between ambient source contribution estimates and emission estimates for urban areas , Watson and Chow[1] made the following recommendations in 2000:

- account for secondary aerosol contributions in estimating the fugitive dust contribution to ambient PM10 concentrations;
- account for global and regional crustal contributions to ambient PM10 concentrations; and
- account for deposition losses and horizontal impaction losses in dispersion models.

Building on the work initiated by Watson and Chow[1], a panel of experts convened by Countess Environmental[2] on behalf of the Western Regional Air Partnership (WRAP) developed a series of 34 recommendations to improve the methodology used to calculate fugitive dust emissions applicable for regional scale air quality modeling for Class 1 areas of the Western US. The key recommendations associated with reconciling emission inventories with ambient measurements were:

- reconcile regional model predictions with measurements by accounting for near source removal of particles;
- develop preliminary estimates of deposition losses for different ground covers for different seasons for a gridded database of land cover across the US; and

- conduct field studies to quantify the "transportable" fraction of fugitive dust emissions (i.e., determining how much of the locally resuspended dust is transported and impacts receptor sites downwind of the source).

The first part of this paper summarizes the progress that has been made since these recommendations were presented at the 10th Annual USEPA Emission Inventory Conference in May 2001. The latter part of this paper describes attempts to reconcile ambient fugitive dust measurements with the PM10 emisssion inventory for the San Joaquin Valley (SJV), an agricultural area of California that is designated as a "serious" PM10 nonattainment area.

## EXPERIMENTAL RESULTS AND DISCUSSION

### Progress Since 2001

The term transportable fraction, proposed by Dale Gillette (see Countess et al.[2]) to describe that fraction of fugitive dust emissions that would escape the nearby surface ground cover and be subject to regional transport, is intended to replace the "divide-by-4" approach used in recent years. First order estimates of transportable fraction have recently been addressed by Cowherd and Pace (2002)[3,4] who proposed that the near-source, near surface depletion of freshly generated fugitive dust plume is composed of two parts: (1) particles that are removed as they pass within and through nearby vegetation, and (2) particles that pass over, but close to the top of the vegetation. Different transportable fractions were assigned to six ground cover categories: 0.97 for barren surfaces and water, 0.85 for agricultural crops, 0.7 for grasses, 0.4 for urban settings, 0.3 for scrub and sparse vegetation, and 0.05 for forested areas. Preliminary estimates of county-level transport fraction using acreage-weighted county land cover characteristics were developed for all counties across the US. In their review of the transportable fractions assigned by Pace and Cowherd, the WRAP fugitive dust expert panel[5] noted that these values would apply only to mechanically resuspended paved and unpaved road dust. The transportable fraction for wind blown dust would be higher since in this case the dust plume would be rapidly mixed vertically and escape the near-source, near surface depletion mechanisms affecting mechanically resuspended paved and unpaved road dust.

To test the hypothesis put forth by Watson and Chow[1] and Countess et al.[2] that fugitive dust particles may deposit to an appreciable extent within several hundred meters of the source, resesearchers from DRI and the University of Utah recently conducted a series of tests involving measurements of fugitive dust emissions from vehicular traffic on unpaved roads[6]. Deposition and impaction losses were found to vary greatly based on setting and atmospheric stability. In arid regions such as the Southwestern US with sparse vegetation and exposed sand, the transportable fraction of unpaved road dust emissions measured 100 meters downwind of the road was close to unity for unstable daytime atmospheric conditions. On the other hand, under stable nighttime atmospheric conditions for large surface roughness elements (simulated by cargo shipping containers) as much as 87% of the PM10 fugitive dust was removed by deposition 95 meters downwind of the unpaved road. It was concluded that this large difference in transportable fraction was due to greater vertical dispersion of the dust plume during neutral and unstable atmospheric conditions compared to stable conditions which retard near-source dispersion and keep the dust plume close to the ground where particles have a better chance to deposit.

Countess Environmental[7] recently completed an assignment for the San Joaquin Valley APCD to estimate the contribution of fugitive dust to ambient PM10 and PM2.5 concentrations in the San Joaquin Valley. This information has been used to develop a fugitive dust control strategy included in the District's 2003 PM10 Attainment Demonstration Plan. The work arising out of this contract that is

relevant to reconciling fugitive dust emission inventories with ambient dust concentrations is presented below.

**Reconciling Ambient Fugitive Dust Concentrations with Emission Inventories: A Case Study**

Fugitive Dust Concentrations

The San Joaquin Valley Air Pollution Control District (District) recently developed a PM10 Attainment Demonstration Plan that addresses implementing control measures for fugitive dust emissions of geological origin to attain both the 24-hour and annual NAAQS PM10 standards. In the fall of 2002 the District contracted with Countess Environmental (CE) to evaluate the impact of fugitive geological dust on ambient PM10 and PM2.5 concentrations in the SJV Air Basin[7]. For this project CE used results from the California Regional Particulate Air Quality Study (CRPAQS) covering the period December 1999 through January 2001. PM10 Minivols, operating at seven sites located throughout the San Joaquin Valley (SJV), collected 24-hour samples every sixth day. During the fall of 2000, daily 24-hour PM10 samples were collected at 11 sites clustered in the Corcoran area, an area that traditionally experiences many violations of the Federal PM10 ambient air quality standards.

Fugitive dust concentrations, [FD], were calculated for each PM10 sample from X-ray Fluoresence (XRF) measurements of individual elements obtained by Desert Research Institute (DRI) as follows:

$$[FD] = 1.89\,[Al] + 2.14\,[Si] + 1.40\,[Ca] + 1.87\,[Fe] + 1.67\,[Ti]$$

This equation assumes that the major elements associated with geological material are present as their predominant oxides (i.e., $Al_2O_3$, $SiO_2$, CaO, $K_2O$, and $TiO_2$), with iron present as an equal mixture of FeO and $Fe_2O_3$. The factor for iron in this equation includes a term to account for potassium associated with geological material, $K_{geol}$, where $K_{geol}$ is equal to the total amount of potassium measured by XRF ($K_{total}$) minus the water soluble potassium ($K_{sol}$) associated with vegetative combustion sources measured by Atomic Absorption, and $K_{geol} = 0.428\ Fe_{geol}$ based on a regression analysis between these two elements using all PM10 Minivol data.

Fugitive dust concentrations appear to be log-normally distributed with 20% of the records greater than 30 $\mu g/m^3$. The annual arithmetic mean and geometric mean fugitive dust concentrations for 2000 for the seven PM10 monitoring sites located throughout the SJV were 18.2 and 13.2 $\mu g/m^3$, respectively. In general the fugitive dust concentrations at these seven sites tracked each other temporally as illustrated in Figure 1. The highest fugitive dust concentrations occurred on September 12, 2000 with the highest concentration of 94.6 $\mu g/m^3$ occurring in Bakersfield. Hourly average wind speeds on this date were relatively light (<7mph); therefore the high levels of fugitive dust on this day are due to anthropogenic sources rather than wind erosion. Precipitation has a strong effect on fugitive dust concentrations. The fugitive dust concentration at the downtown Fresno site decreased from 61.3 $\mu g/m^3$ on October 6 to 4.7 $\mu g/m^3$ on October 12 after 1 inch of rain fell during the previous two days, and from 30.8 $\mu g/m^3$ on October 24 to 7.8 $\mu g/m^3$ on October 30 after 0.55 inch of rain the previous day. Fugitive dust concentrations were statistically higher on weekdays (20.0 $\mu g/m^3$) compared to weekends (14.2 $\mu g/m^3$).

The monthly average fugitive dust/mass ratios at the seven PM10 monitoring sites located throughout the SJV tracked each other temporally for most months as illustrated in Figure 2. The highest monthly PM10 fugitive dust/mass ratios occurred between May 2000 and September 2000. Figure 2 indicates that the fugitive dust/mass ratio appears to be split into two modes, with a ratio of >0.5 between April and September when fugitive dust predominates over other chemical species and a ratio of <0.5 between October and March when secondary ammonium nitrate predominates.

Fugitive Dust Emission Estimates

According to the District's PM10 emission inventory for the SJV Air Basin for 2000 fugitive dust accounts for 78.5% of the total primary PM10 emissions. However, based on ambient measurements made at the seven PM10 monitoring sites located throughout the SJV in 2000, the annual average PM10 fugitive dust concentration accounted for 51% of the PM10 mass. This discrepancy in the contribution of fugitive dust to total mass between ambient measurements and emission inventory estimates is caused by:

- the emissions inventory not taking into account secondary sources of particulate material, and
- a portion of the freshly generated fugitive dust emissions depositing out on the ground or on the surfaces of various obstructions (e.g., buildings, vegetation) close to the source.

According to the District, approximately 86% of the fugitive dust emissions are due to paved road dust, unpaved road dust (most of which is associated with agricutural operations), tilling and harvesting operations, and construction/demolition. Wind erosion of exposed surfaces of geological material accounts for the balance. These results are summarized in Table 1 together with primary PM2.5 emission estimates based on measured PM2.5/PM10 ratios for the different source categories[8,9].

Several years ago Countess[10] estimated that gas phase precursor emissions that produced secondary PM10 were equal to 71% of the primary PM10 emissions for the South Coast Air Basin in 1993. Thus, although fugitive dust emissions contributed 84% of the primary PM10 emissions, their contribution decreased to 49% when one accounted for both primary PM10 emissions and gas phase precursor emissions of secondary PM10.

A first-order estimate of gas phase precursor emissions of secondary PM10 for the San Joaquin Valley for 2000 was calculated using the methodology of Countess[10] with the following assumptions:

- all sulfate, nitrate, and ammonium in excess of regional background levels is secondary in origin,
- secondary organic carbon, OC, is equal to total OC in excess of regional background levels minus primary OC in excess of regional background levels;
- sampling artifacts associated with OC are negligible;
- the organic carbon/elemental carbon (OC/EC) split measured by DRI is correct; and
- agricultural burning, with a primary OC/EC ratio of 3.47[11], is the dominant source of OC in the San Joaquin Valley.

This estimate required several steps utilizing annual average concentrations for 2000. First the contribution from local sources to the ambient concentrations of the chemical species of interest (ammonium nitrate and sulfate, organics, and elemental carbon) in the PM2.5 size fraction was calculated for each of the 29 PM2.5 monitoring sites located throughout the SJV by correcting for the regional background concentrations measured at a rural upwind site located outside the SJV. Ammonium nitrate was calculated by multiplying the nitrate concentration by 1.29, ammonium sulfate was calculated by multiplying the sulfate concentration by 1.38), and organic compounds were calculated by multiplying the OC concentration by 1.4 to account for unmeasured hydrogen and oxygen. The second step involved calculating the fraction of OC due to local sources that was secondary using the background corrected OC and EC concentrations and a primary OC/EC ratio of 3.47 for agricultural burning. The third step involved calculating the ratio of the sum of the background corrected concentrations of secondary PM2.5 species divided by the background corrected PM2.5 mass concentration for each of the 29 PM2.5 monitoring sites, and then calculating the average ratio of all sites. Annual average PM2.5 concentrations for the chemical species of interest are summarized in Table 2.

Utilizing the average background corrected concentrations presented in Table 2, the fraction of secondary PM2.5 species contributing to total PM2.5 mass due to both primary and secondary sources was calculated as follows: $2^o/(1^o + 2^o) = (3.7+0.4+[4.1-3.47*0.7])/8.9 = 0.65$. This estimate suggests that secondary PM2.5 emissions are approximately 1.8 times (i.e., 0.65/0.35) larger than the primary PM2.5 emissions, resulting in an estimate of secondary PM2.5 emissions of 286 tons/day (i.e., 1.8*155 tons/day). Combining this estimate of secondary PM2.5 emissions with the District's estimate of 465 tons/day of primary PM10 emissions results in secondary emissions of PM10 accounting for 38% of the total daily PM10 emissions for the San Joaquin Valley for 2000. Thus, although fugitive dust emissions contributed 78.5% of the primary PM10 emissions, their contribution drops to 49% when one accounts for both primary and secondary PM10 emissions. These results are similar to those calculated for the South Coast Air Basin for 1993[10].

For time periods during 2000 when sources of carbonaceous aerosol other than agricultural burning such as light duty gasoline vehicles, heavy duty diesel vehicles, or residential wood combustion (RWC) were important, estimates of the fugitive dust's contribution to total primary and secondary PM10 emissions would be very different from that presented above due to different OC/EC ratios for the different source categories. Estimates of the fugitive dust's contribution to total primary and secondary PM10 emissions are summarized in Table 3 for different scenarios regarding the dominant source of carbonaceous aerosols in the SJV.

Estimating Transportable Fraction for SJV Based on Land Cover

The calculated transportable fraction (TF) for mechanically resuspended fugitive dust for each of the eight counties comprising the SJV are presented in Table 4 utilizing the TFs assigned by Pace and Cowherd[4] to six different land cover categories. The overall TF for each county was calculated using a weighted average of the vegetation in each county and the TF for that type of vegetation. The county-level land use data was derived from the BELD database. The TFs for the eight counties in the SJV range from 0.34 for Tulare County that is heavily forested to 0.74 for Kings County that has a large portion of the county devoted to agricutural crops. The TF for the entire SJV was estimated to be 0.54.

Estimating Transportable Fraction for SJV Based on Ambient Measurements

Daily PM10 samples were collected during the fall of 2000 at 10 sites clustered within a 3-mile by 3-mile zone centered in the Corcoran area plus an upwind site located approximately 15 miles northwest in order to investigate the spatial variation in fugitive dust concentrations. Based on historical PM10 records, this area of the SJV located in Kings County is heavily impacted by agricultural operations during the fall. Local sources of fugitive dust in this area include cotton handling, grain elevators, unpaved shoulders and railroad tracks, as well as paved and unpaved dairy roads. For two sites located downwind (for the prevailing northwest winds) of extensive cotton handling operations, the near downwind site had the highest fugitive dust concentrations of all 11 sites during the fall of 2000 and the site located an additional one mile downwind had the lowest fugitive dust concentrations. For the 15 days with valid XRF results for both sites, the average PM10 fugitive dust concentration at the far downwind site was 72% of that for the near downwind site. On the other hand, ammonium nitrate, ammonium sulfate and elemental carbon were approximately equal at both sites. Organic carbon at the far downwind site was 85% of that measured at the near downwind site, suggesting the possibility that OC exists in both the fine and coarse size fractions. The ground cover between the near downwind site and the far downwind site during this period consisted of barren agricultural fields upon which were stored cotton "modules" (i.e., ~8 foot high bales of processed cotton) and barren earth with sparse grass

cover. Wind speeds during this time period were relatively light with daily average wind speeds less than 3 mph.

Relative Abundance of Soil Elements in PM2.5 and PM10 Size Fractions

Colocated PM2.5 Minivols and PM10 Minivols were operated at four sites in the SJV during the CRPAQS study. However, because the two samplers did not operate on the same days (PM2.5 and PM10 sampling was staggered three days apart) it was not possible to calculate a PM2.5/PM10 ratio for fugitive dust for the same sampling days. Combining all PM2.5 and PM10 Minivol records collected over the 14-month CRPAQS monitoring period produced PM2.5/PM10 fugitive dust ratios for the four sites that were about one-third to one-half that of USEPA's estimates[12] of 0.15 to 0.25 for fugitive dust sources (paved and unpaved roads, construction, farming and mining operations). This finding is related to the discovery made by this investigator that the Si/Fe and Al/Fe ratios for the PM2.5 size fraction based on XRF results reported by DRI were significantly lower (factor of two to three) than the comparable ratios for the PM10 size fraction. For example, the average Si/Fe ratio for ambient CRPAQS samples was 4.5 for the PM10 size fraction and 1.5 for the PM2.5 size fraction. DRI has subsequently confirmed that other XRF results from 10 other field studies conducted over the past several years support this observation. This finding merits further investigation since the source profiles for fugitive dust sources (most of which were generated over 15 years ago) included in SPECIATE[13] indicate relatively uniform Si/Fe ratios as a function of particle size for four different particle size ranges (0 - 2.5 μm, 2.5 - 10 μm, 0 - 10 μm, and 0 - 30 μm) for a specific fugitive dust source. Since very few of the source profiles generated over 15 years ago included direct measurements of the PM2.5 size fraction, it is highly probable that these source profiles assumed a uniform chemical composition across all size ranges. It is important to point out that the Si/Fe ratios given in SPECIATE cover a relatively broad range. For four different source profiles generated in 1987 by the same laboratory (NEA Inc.), the Si/Fe ratio is 2 for a Los Angeles composite paved road dust sample, 3.6 for unpaved road dust from Riverside, 5 for the earth's crust, and 6.7 for crustal sediment. It appears that the Si/Fe ratio decreases as the geological material becomes more abraded.

The average ratio of the major elements associated with geological material in the PM2.5 and PM10 size fractions for the four sites with colocated PM2.5 and PM10 Minivols are presented in Table 5. Potassium is not shown in this table since the potassium measured by XRF includes potassium from geological material, which tends to be primarily in the coarse size range, and potassium originating from vegetative combustion, which tends to be primarily in the fine size range. Table 5 indicates that the major elements associated with fugitive geological dust are not distributed uniformly between the fine and coarse size fractions. There is a smaller percentage in the PM2.5 size fraction relative to the PM10 size fraction for the two dominant elements aluminum and silicon compared to calcium, titanium and iron, namely ~5% versus 10-16%. Consequently, the average PM2.5/PM10 ratio for fugitive dust, which is dominated by aluminum and silicon, is only 0.06 compared to 0.15 to 0.25 reported in AP-42[12].

## CONCLUSIONS

The actual impact of fugitive dust emissions on ambient air quality and associated visibility impairment at downwind receptor sites is significantly less than estimates based on fugitive dust emission rates measured at the source. This is due to deposition losses of particles both from impaction with surfaces of obstructions (e.g., vegetation) as well as gravitational losses to the ground. A considerable amount of progress has been made in the past two years since recommendations were published for reconciling fugitive dust emission estimates with actual ambient measurements[2]. The notion of using a one-size-fits-all approach such as the "divide by four" approach has been abandoned in favor of deriving estimates of transportable fraction for different land cover categories at the county

level[3,4]. Field studies have been designed to quantify the transportable fraction for mechanically resuspended unpaved road dust for different land cover categories and for different atmospheric conditions[6]. Results from a large ambient PM10 monitoring network have been assessed to develop first order estimates of the fugitive dust transportable fraction[7].

Emission inventories tend to overestimate the contribution of fugitive dust to ambient PM10 levels unless they take into account secondary sources of particulate material as demonstrated by Countess[10]. It is also well known that ambient fugitive dust concentrations are affected by global and regional fugitive dust emission sources. To date few investigators have attempted to quantify the role of secondary particulate material (e.g., ammonium nitrate, ammonium sulfate and organic aerosol compounds) or the role of emissions from primary and secondary particulate sources originating from areas outside the local area. Developing these estimates is complicated by the fact that little is known regarding the contribution from secondary organic aerosol compounds, the chemical transformation of the aerosol in the atmosphere after it is released from its source, or the change in particle size distribution with time as the aerosol ages and the larger particles are preferentially lost by various deposition mechanisms compared to the smaller particles.

Estimating the transportable fraction for fugitive dust for Kings County located in the San Joaquin Valley by two different methods, one based on estimates of transportable fraction for different land cover categories and one based on ambient measurements, gave surprisingly consistent results. To improve the estimates derived from ambient measurements would require sampling ambient PM10 levels for shorter time periods than the 24-hour sampling periods used in CRPAQS or conducting a study especially designed to quantify the transportable fraction such as the study conducted by Etyemezian et al.[6].

The ratio of fugitive dust in the PM2.5 and PM10 size fractions for four monitoring sites in the SJV was one-third to one-half that published by EPA[12] for different fugitive dust source categories due to the fact that the relative abundance of the two major elements associated with geological material, silicon and aluminum, are approximately a factor of two to three lower in the PM2.5 size fraction compared to the PM10 size fraction. This finding merits further investigation since the 15-year old source profiles for fugitive dust sources included in SPECIATE[13] indicate uniform relative abundances for the different soil related elements as a function of particle size for a specific fugitive dust source.

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**Keywords**

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**Figure 1. Temporal variation in PM10 fugitive dust concentrations.**

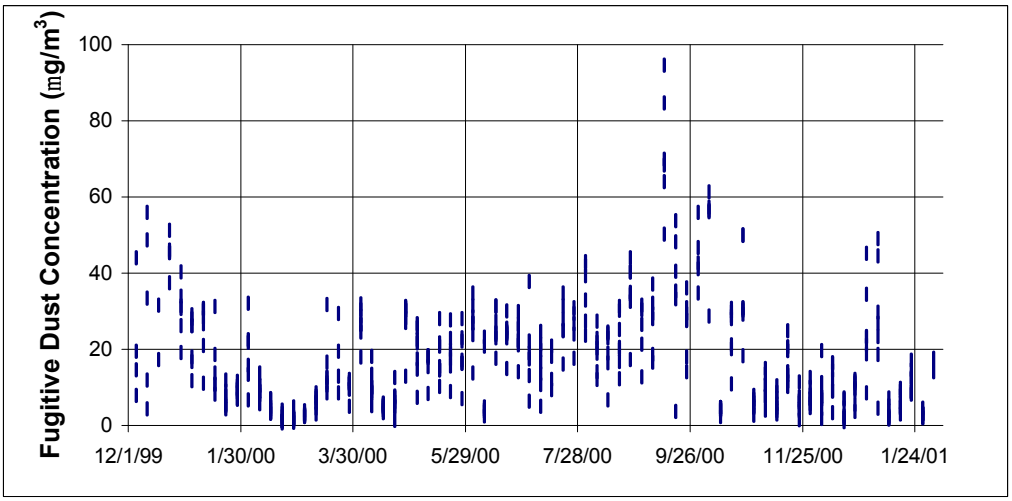


**Figure 2. Temporal variation in monthly PM10 fugitive dust/mass ratios at 7 sites (12/99-1/01).**

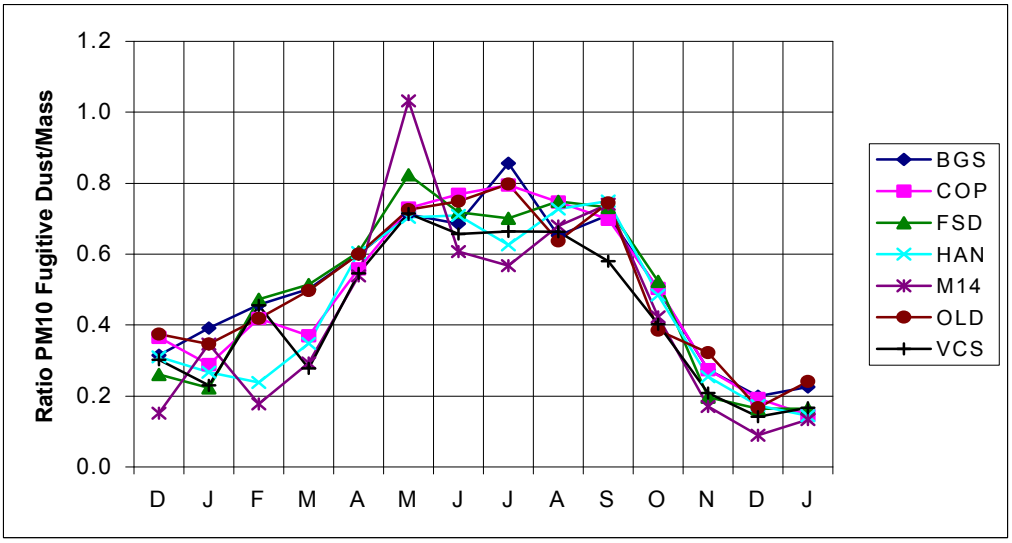

**Table 1. Average daily primary PM10 and PM2.5 emission inventory for SJV for 2000.**

| Source Category | PM10 (tons/day) | PM2.5/PM10 Ratio | PM2.5 (tons/day) |
|---|---|---|---|
| **Stationary Sources** | | | |
| Fuel Combustion[a] | 21.02 | 0.96[b] | 20.18 |
| Petroleum Processes | 1.44 | 0.90[b] | 1.30 |
| Industrial Processes | 19.44 | 0.56[b] | 10.88 |
| Total Stationary Sources | 41.90 | | 32.36 |
| **Fugitive Dust Sources** | | | |
| Paved Road Dust | 63.97 | 0.25[c] | 15.99 |
| Unpaved Road Dust | 114.19 | 0.15[c] | 17.13 |
| Construction & Demolition | 24.47 | 0.15[c] | 3.67 |
| Farming Operations | 111.28 | 0.20[c] | 22.26 |
| Fugitive Windblown Dust | 51.13 | 0.15[c] | 7.67 |
| Total Fugitive Dust Sources | 365.04 | | 66.72 |
| **Miscellaneous Processes** | | | |
| Waste Burning | 40.15 | 0.96[b] | 38.55 |
| Solvent Use | 0.09 | 0.96[b] | 0.09 |
| Unplanned Fires | 0.16 | 0.93[b] | 0.15 |
| Cooking | 1.93 | 1.00[b] | 1.93 |
| Other | 0.02 | 0.61[b] | 0.01 |
| Total Misc. Processes | 42.35 | | 40.73 |
| **Mobile Sources** | | | |
| On-Road | 6.67 | 0.98[b] | 6.54 |
| Other | 9.01 | 0.98[b] | 8.83 |
| Total Mobile Sources | 15.69 | | 15.38 |
| **Total All Souces** | 464.98 | | 155.18 |

[a]Includes residential fuel combustion
[b]PM2.5/PM10 ratio obtained from Gaffney (1998)[8]
[c]PM2.5/PM10 ratio obtained from Cowherd and Kuykendal (1997)[9]

**Table 2. Annual average PM2.5 concentrations (μg/m$^3$) for SJV for 2000.**

| | Ammonium Nitrate | Ammonium Sulfate | Organic Compounds | Elemental Carbon | Mass |
|---|---|---|---|---|---|
| SJVAB Sites | 6.9 | 2.1 | 8.0 | 2.0 | 17.1 |
| Background Site | 3.2 | 1.7 | 3.9 | 1.3 | 8.2 |
| Net Concentration due to local sources | 3.7 | 0.4 | 4.1 | 0.7 | 8.9 |

**Table 3. Fugitive dust's contribution to total PM10 emissions for different scenarios.**

| Dominant Source of Carbonaceous Aerosol | OC/EC | $2^o/(1^o + 2^o)$ | $2^o/1^o$ | $FD/(1^o + 2^o)$ |
|---|---|---|---|---|
| Agricultural burning | 3.47 | 0.648 | 1.84 | 0.49 |
| Light duty gasoline vehicles | 3.64 | 0.635 | 1.74 | 0.50 |
| Heavy duty diesel trucks | 1.13 | 0.832 | 4.97 | 0.30 |
| RWC, fireplaces | 2.45 | 0.729 | 2.69 | 0.41 |
| RWC, wood stoves | 5.83 | 0.463 | 0.86 | 0.61 |

**Table 4. Transportable fraction by county for SJV.**

| Land Use Category | Water & Barren | Ag Crops | Grasses | Urban | Scrub & Sparse Veg | Forest | TF |
|---|---|---|---|---|---|---|---|
| **TF by Category** | 0.97 | 0.85 | 0.70 | 0.40 | 0.30 | 0.05 | |
| **County** | **Fractional Land Use by County** | | | | | | |
| Fresno | 0.001 | 0.48 | 0.085 | 0.021 | 0 | 0.41 | 0.50 |
| Kern | 0.057 | 0.28 | 0.29 | 0.012 | 0.21 | 0.21 | 0.58 |
| Kings | 0.002 | 0.87 | 0 | 0 | 0 | 0.13 | 0.74 |
| Madera | 0.001 | 0.35 | 0.14 | 0 | 0 | 0.51 | 0.42 |
| Merced | 0.019 | 0.66 | 0.20 | 0.008 | 0 | 0.13 | 0.73 |
| San Joaquin | 0.020 | 0.81 | 0 | 0.054 | 0 | 0.13 | 0.74 |
| Stanislaus | 0.001 | 0.59 | 0.20 | 0.032 | 0 | 0.18 | 0.66 |
| Tulare | 0.001 | 0.25 | 0.10 | 0.006 | 0.10 | 0.54 | 0.34 |
| All Counties | 0.019 | 0.43 | 0.16 | 0.014 | 0.08 | 0.32 | 0.54 |

**Table 5. PM2.5/PM10 ratio for elements associated with geological material.**

| Site | Al | Si | Ca | Ti | Fe | FD[a] |
|---|---|---|---|---|---|---|
| Corcoran | 0.048 | 0.070 | 0.14 | 0.09 | 0.10 | 0.074 |
| Modesto | 0.034 | 0.035 | 0.20 | 0.12 | 0.10 | 0.049 |
| Oildale | 0.055 | 0.052 | 0.15 | 0.13 | 0.10 | 0.063 |
| Visalia | 0.048 | 0.050 | 0.13 | 0.15 | 0.11 | 0.061 |
| Average | 0.046 | 0.052 | 0.16 | 0.12 | 0.10 | 0.062 |

[a]FD = fugitive dust