Resuspension of Contaminated Soil as a Source of Airborne Lead

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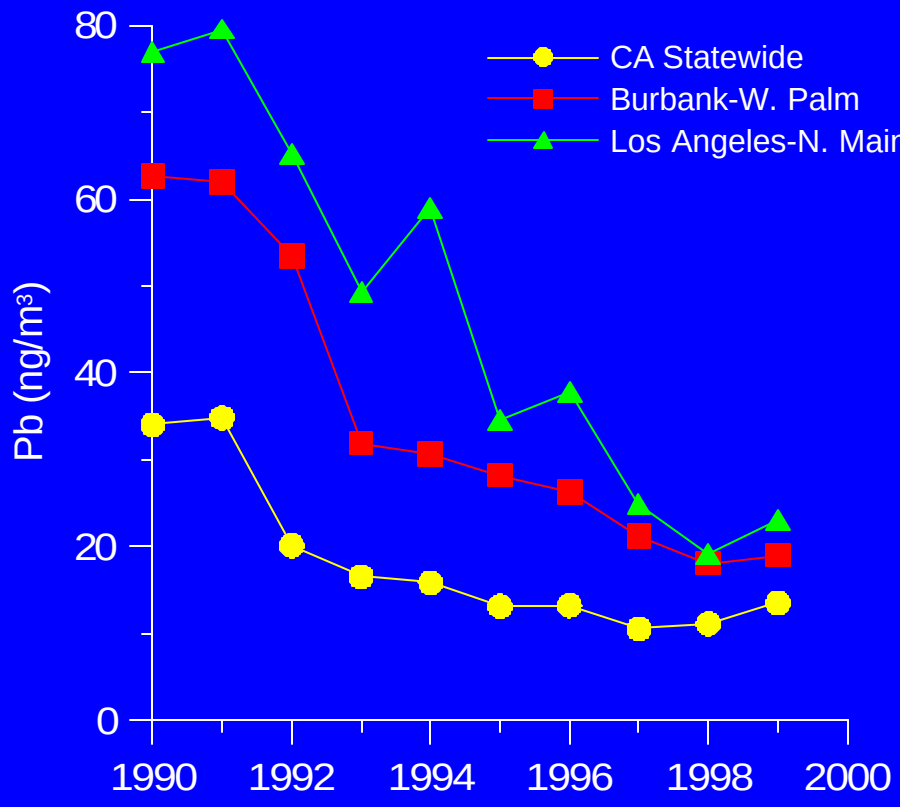
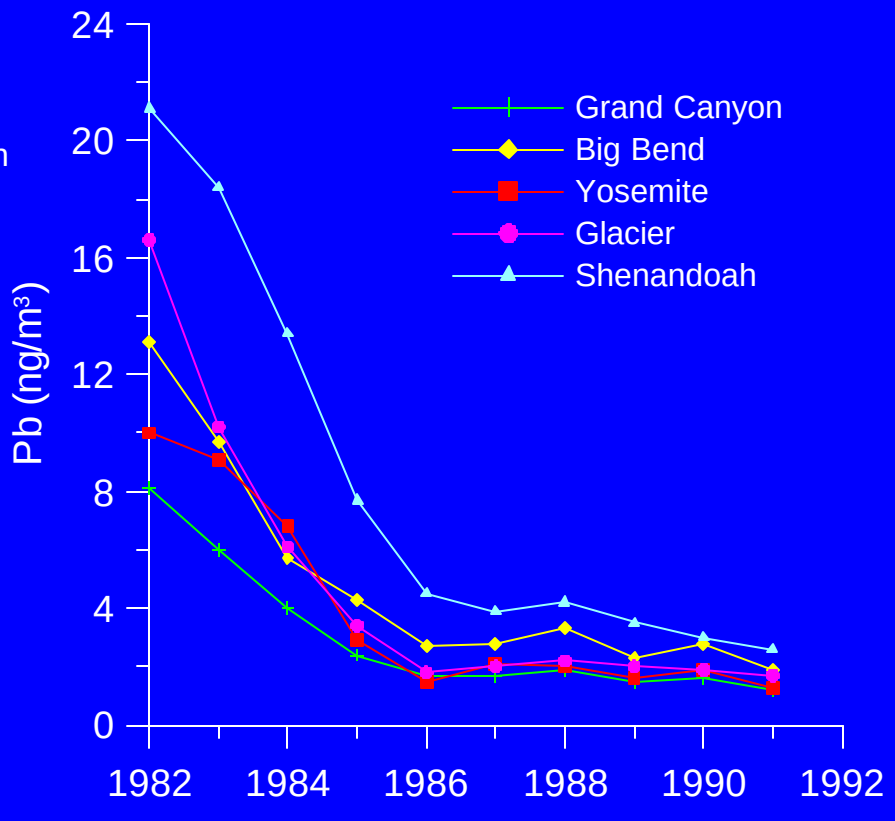
Declining Average Pb Levels

Urban sites



California Air Resources Board, 2000

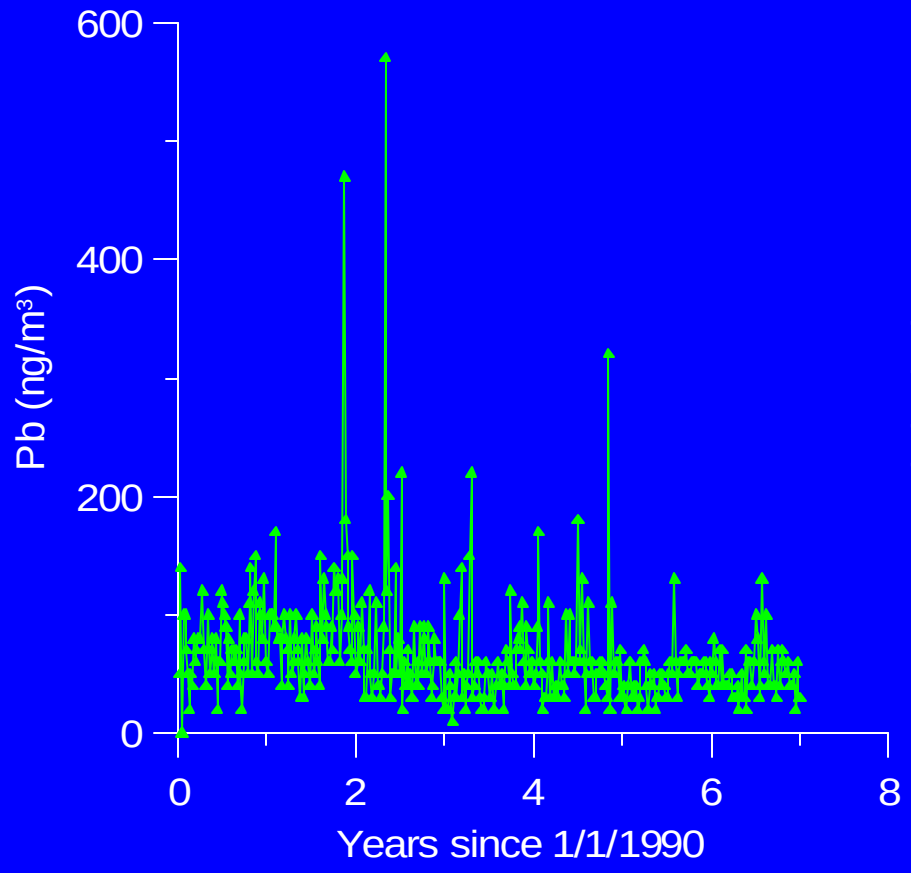
Remote sites



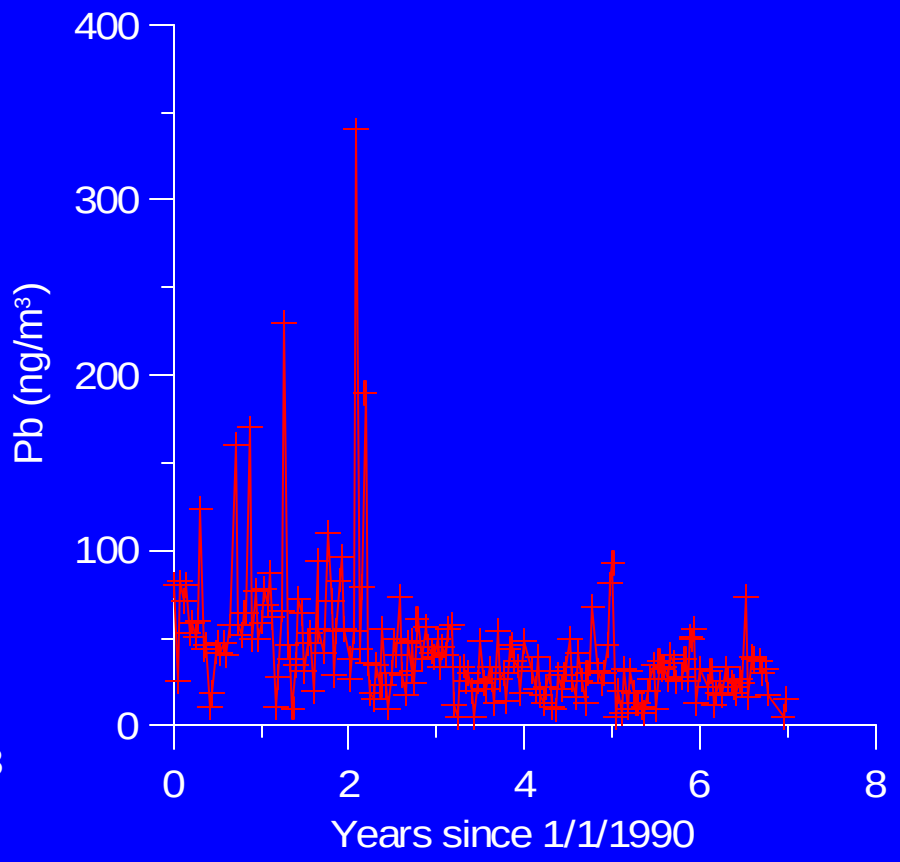
Eldred and Cahill, 1994

Daily Pb Variability

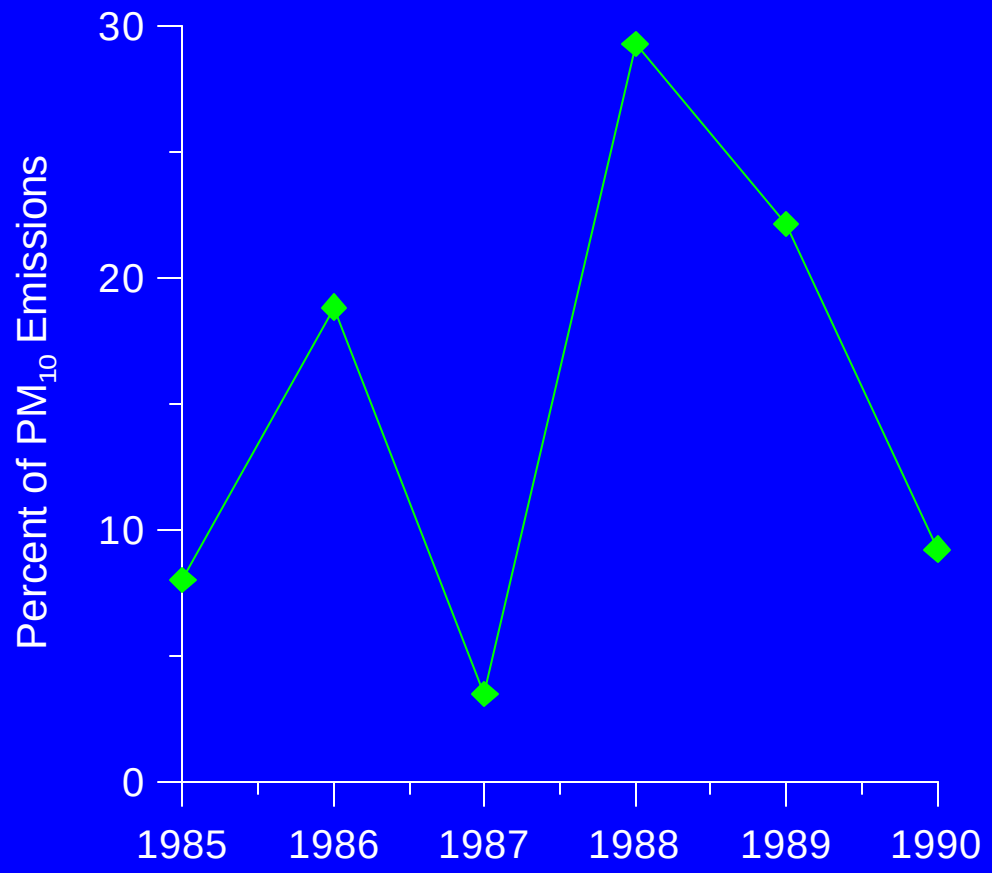
Los Angeles-N. Main



Burbank-W. Palm



Wind Erosion Contribution to PM_{10}



Barnard et al., 1992

Research Questions

- Do Pb-contaminated soils contribute significantly to airborne Pb levels?
- How does Pb concentration on fine particles relate to soil Pb levels?
- Are there particular co-contaminants in Pb contaminated soil that serve as industry markers?

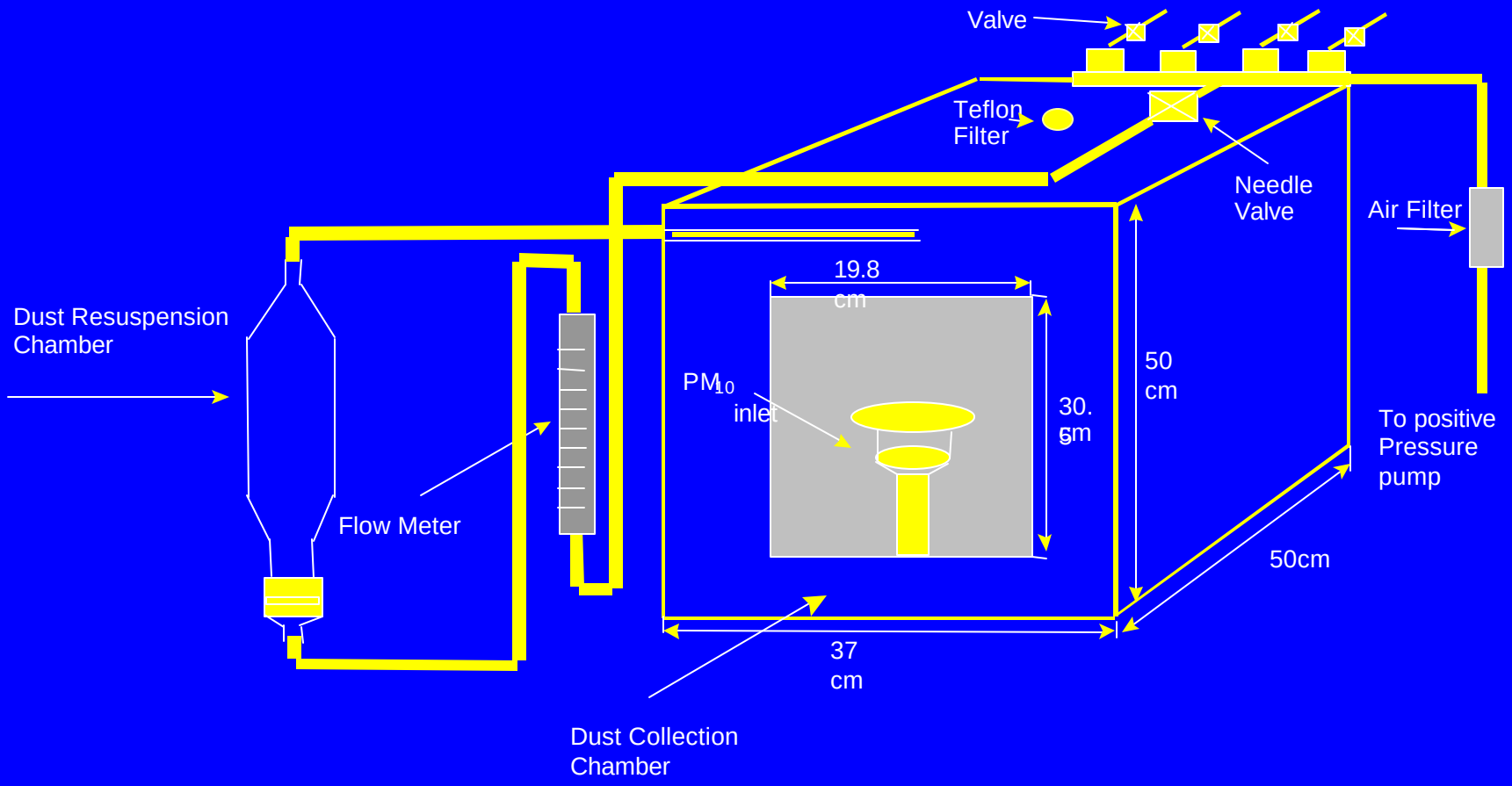
Study Design—Soil Collection

- Site selection
  - Facilities selected from ARB and DTSC lists of Pb emitters or sites with Pb contamination
- Field sampling
  - Few facilities provided access
  - Took soil cores (0-6”) on or near 8 industrial facilities

Study Design--Analytical

- Bulk soils
  - Pb, Cu, Ni, Zn measured by XRF
  - Dry sieving to size fractionate
- Resuspension
  - PM_{10} generated from soil samples after drying
- Filter analyses
  - Pb and 18 other elements (S, Cl, K, Ca, Ti, Mn, Fe, Cu, Zn, Ga, Hg, As, Se, Br, Rb, Sr, Y, Zr) measured by XRF

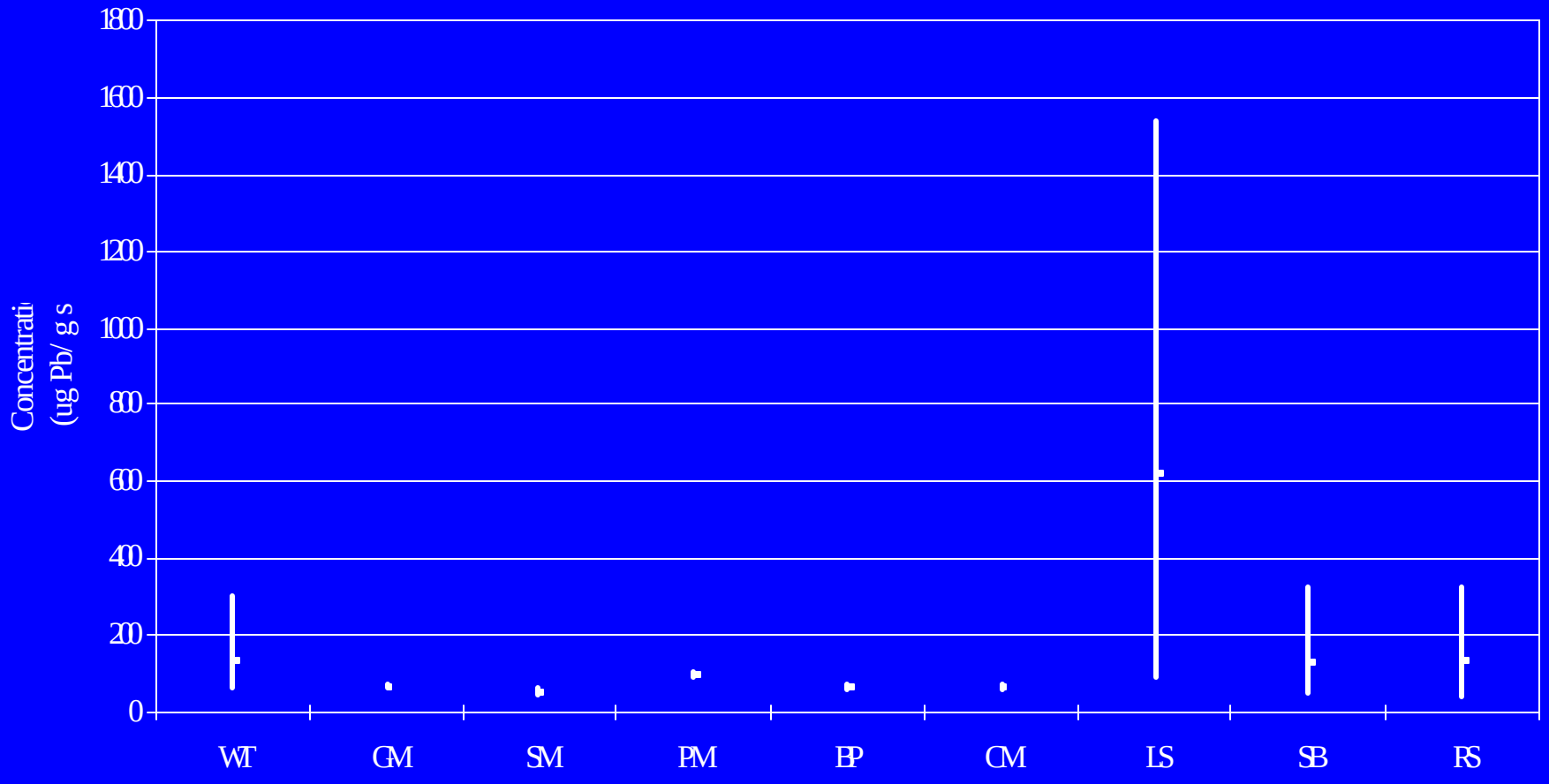
Resuspension System



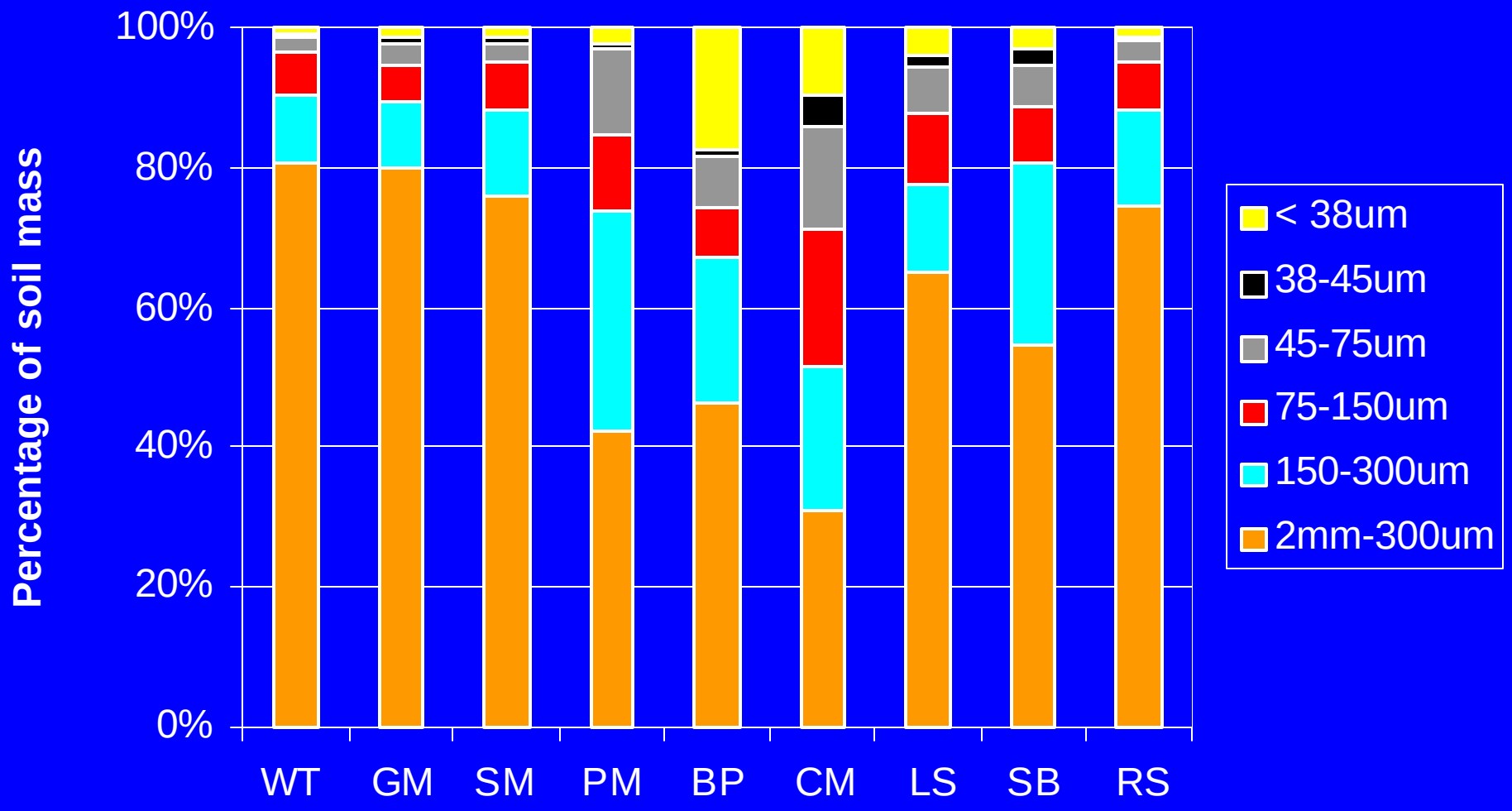
Summary of Sites and Samples

Site	Type of Site	Samples Collected	Source Distance (m)	Resuspension
WT	Waste Treatment	5	7-182	No
GM	Glass Manufacturing	4	64-71	Yes
SM	Saw Mill	2	44-63	No
PM	Perlite Mining	4	98-105	Yes
BP	Borax Processing	6	60-73	Yes
CM	Cement Manufacturing	8	58-69	No
LS	Lead Smelter	9	123-256	Yes
SB	Sand Blasting	12	1-35	Yes
RS	Roadside	2	1-6	Partial

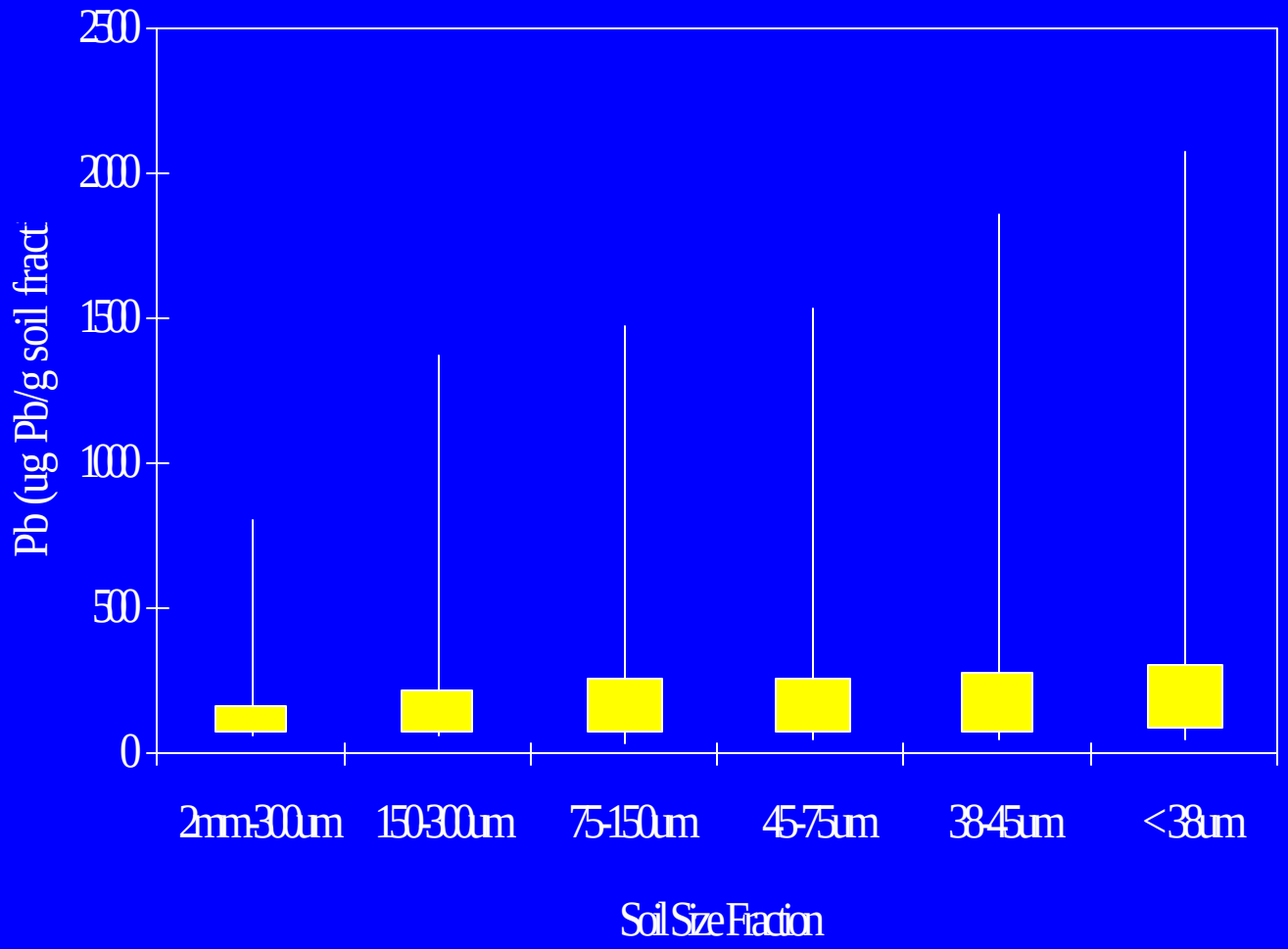
Soil Pb Concentration by Site



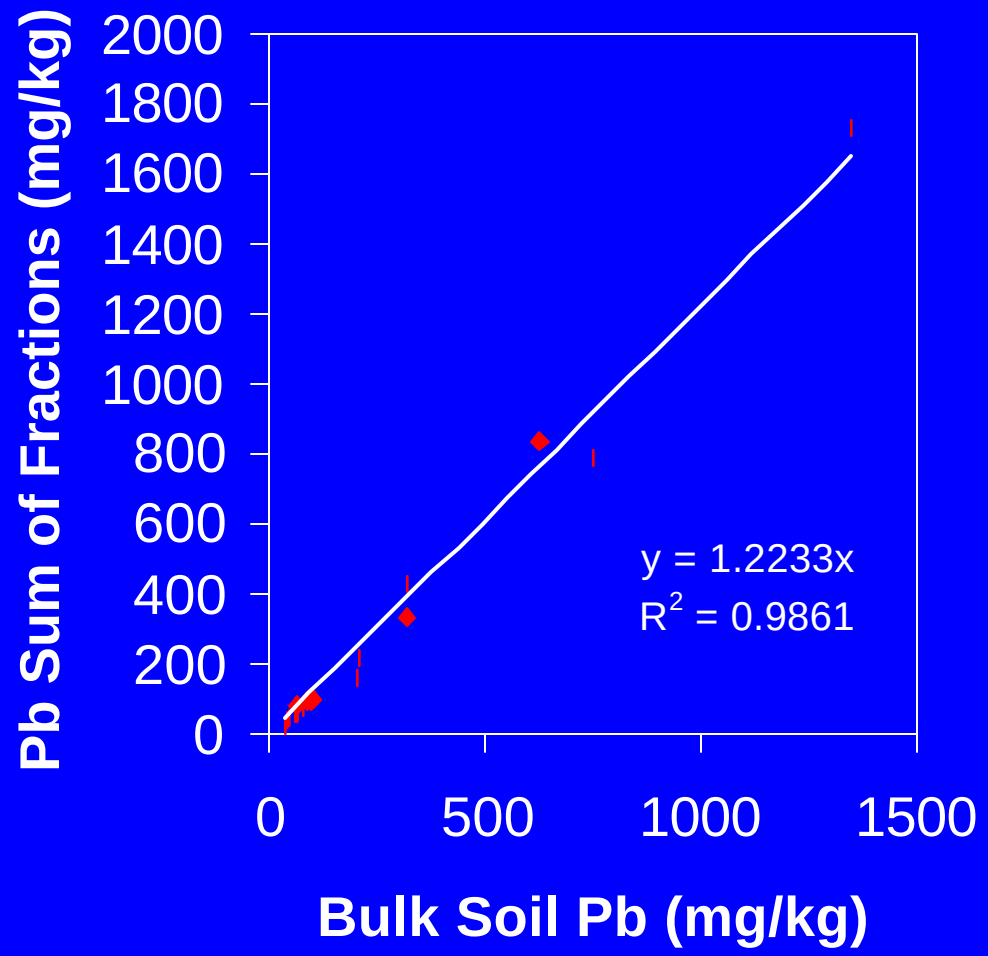
Soil Particle Size Distributions



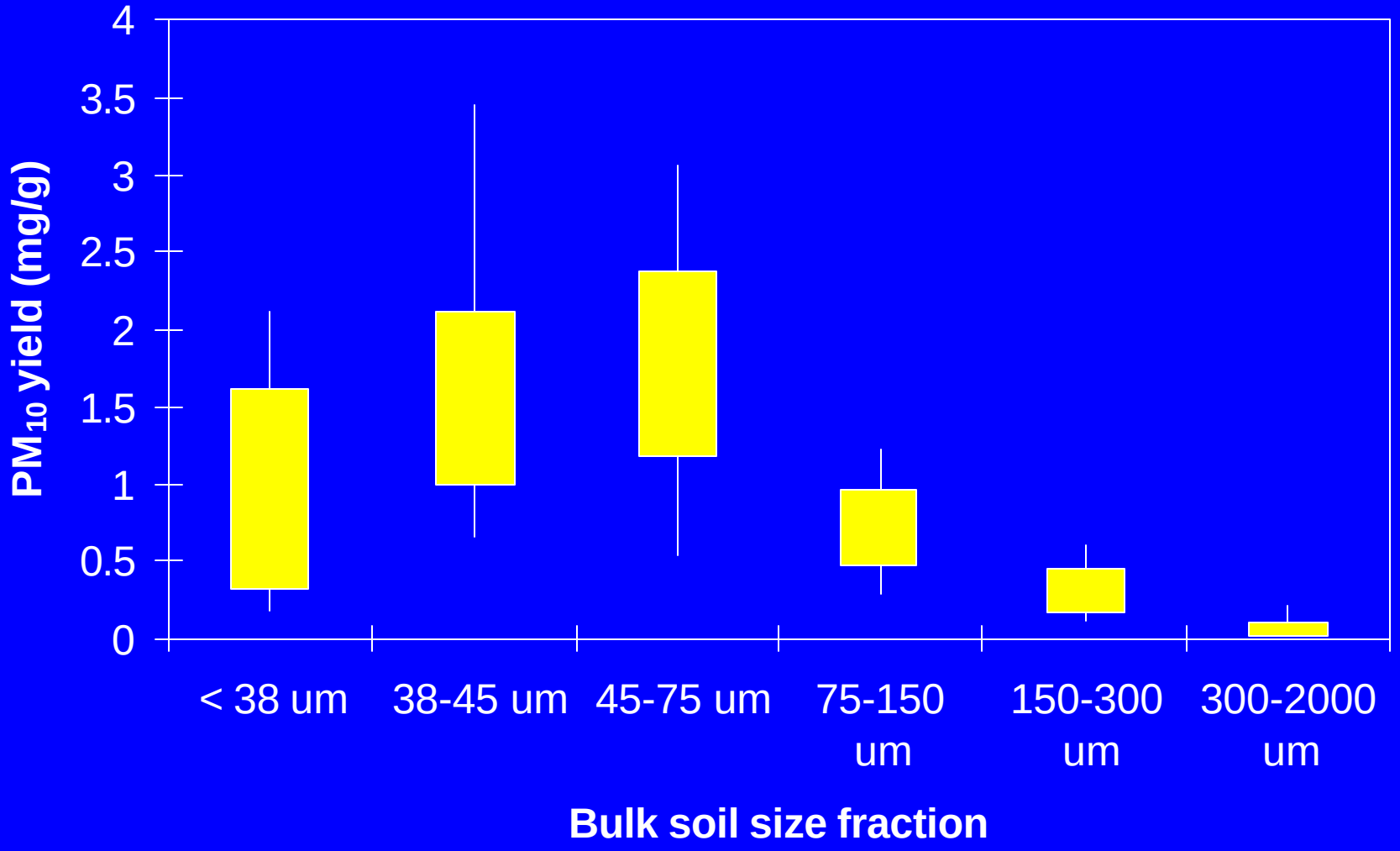
Pb Distribution by Particle Size



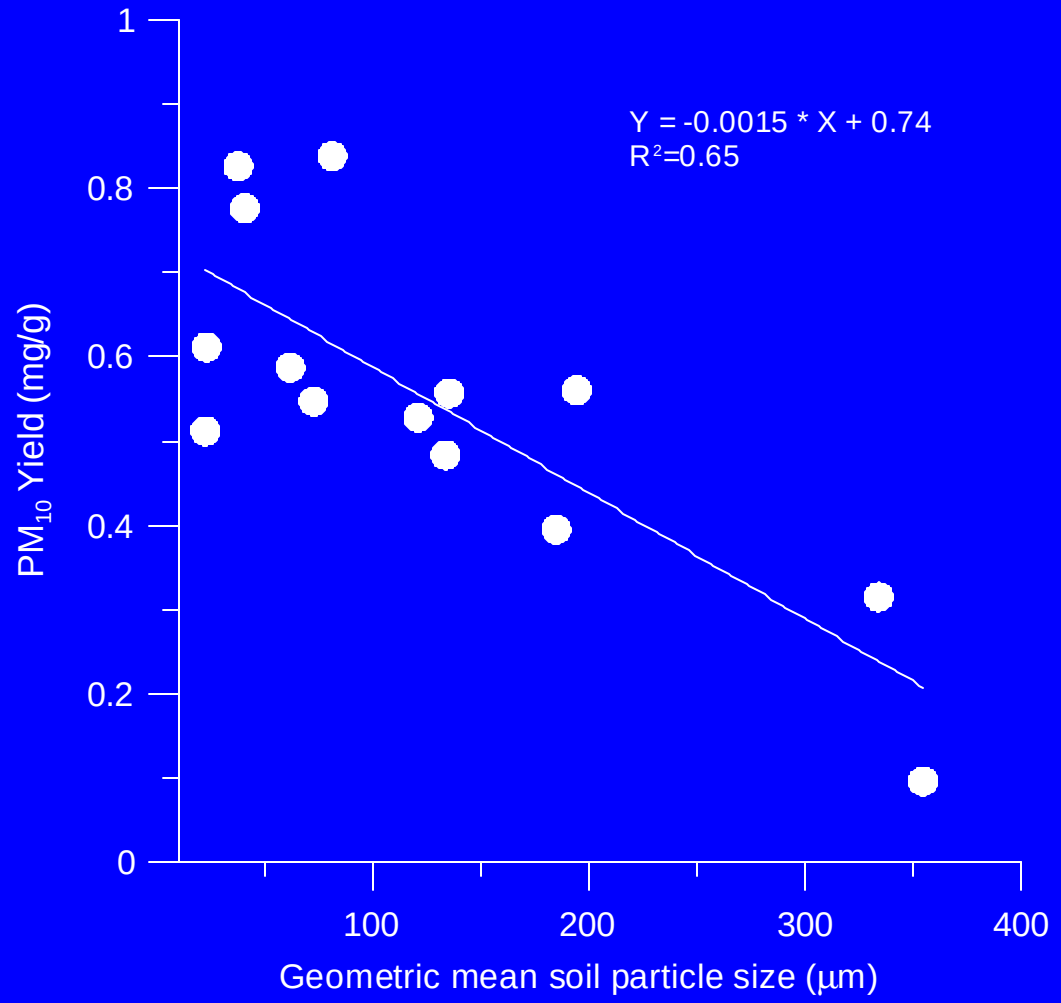
Checking Fractional Pb Data



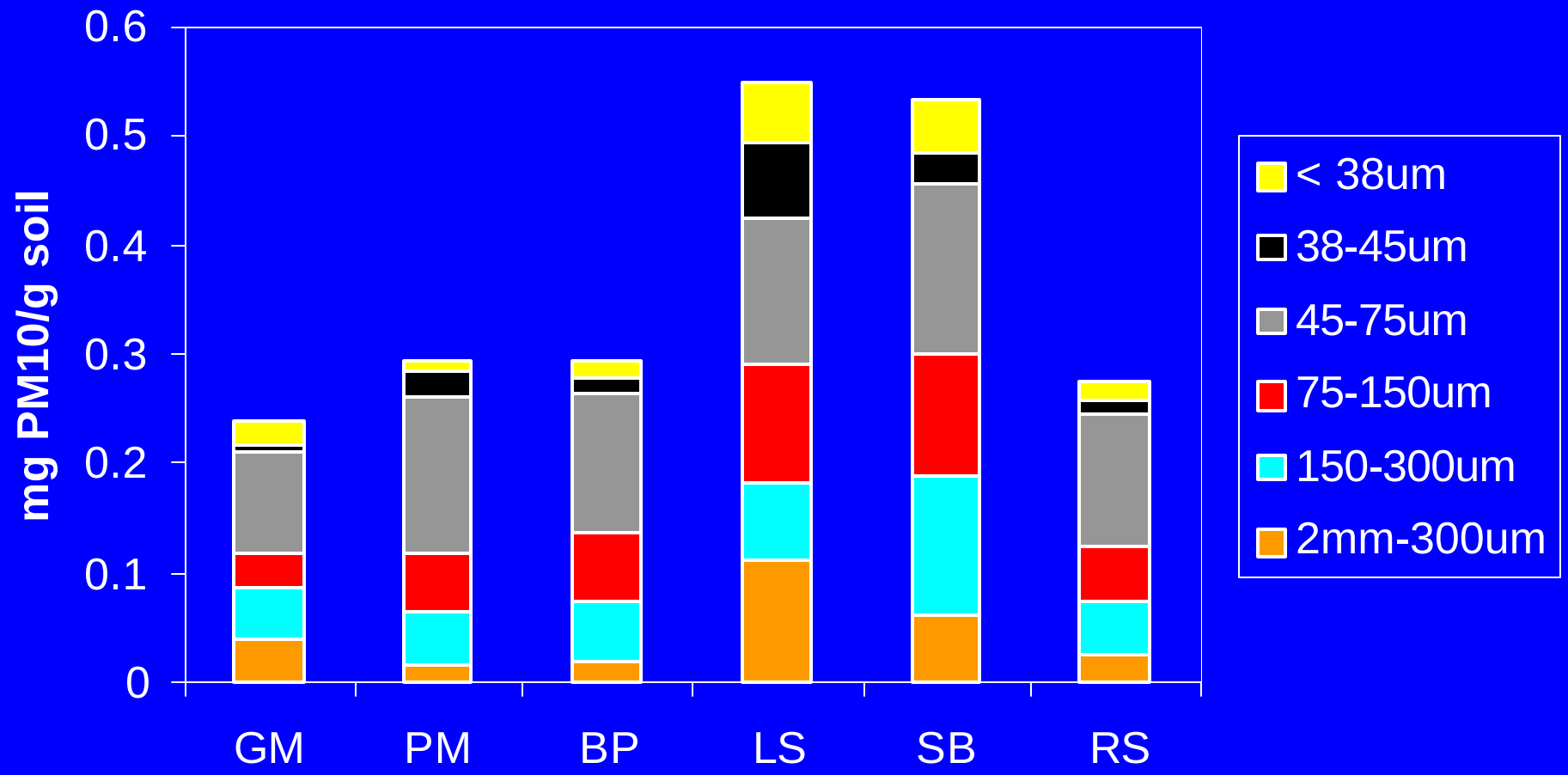
PM_{10} Yield by Size Fraction



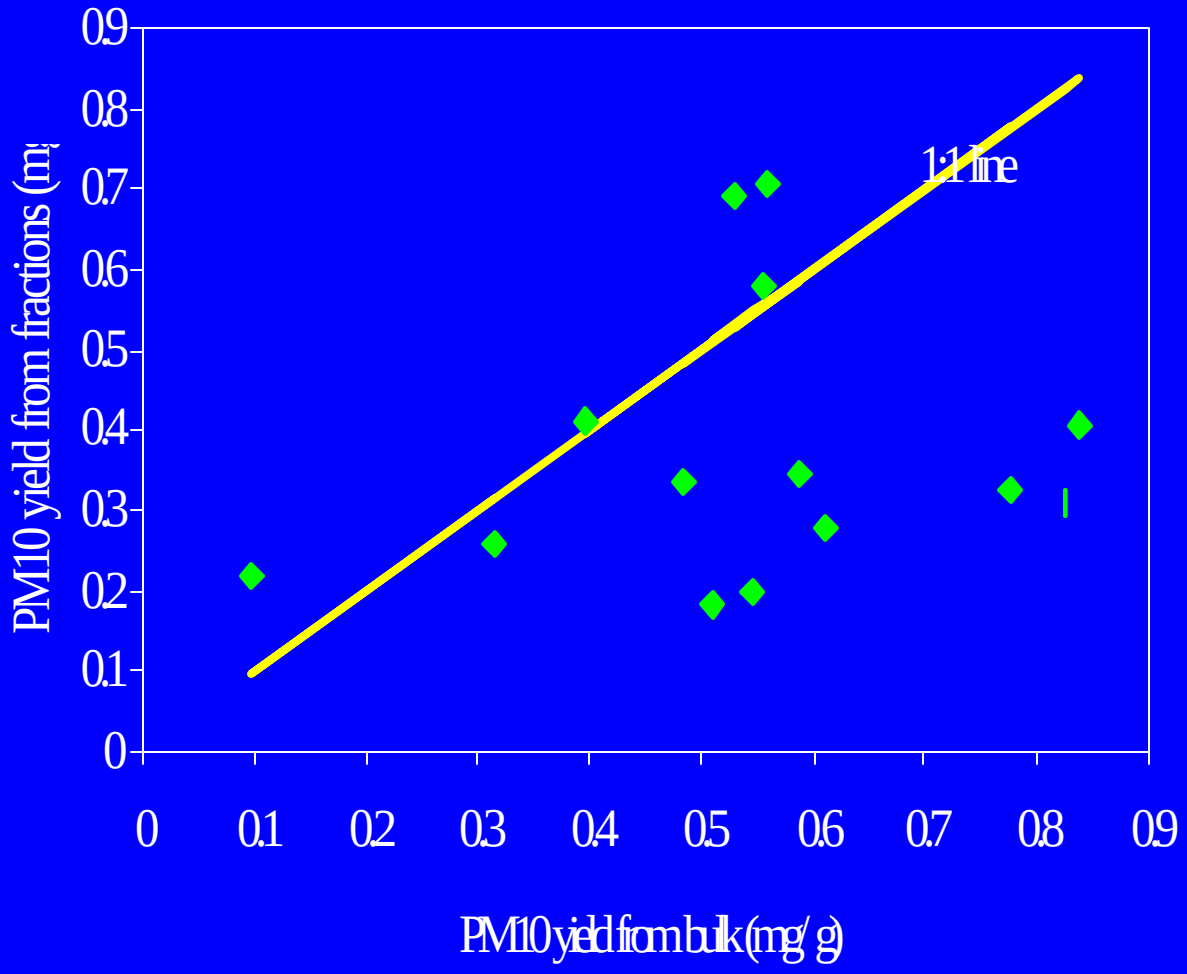
Effect of particle size on PM_{10} Yield



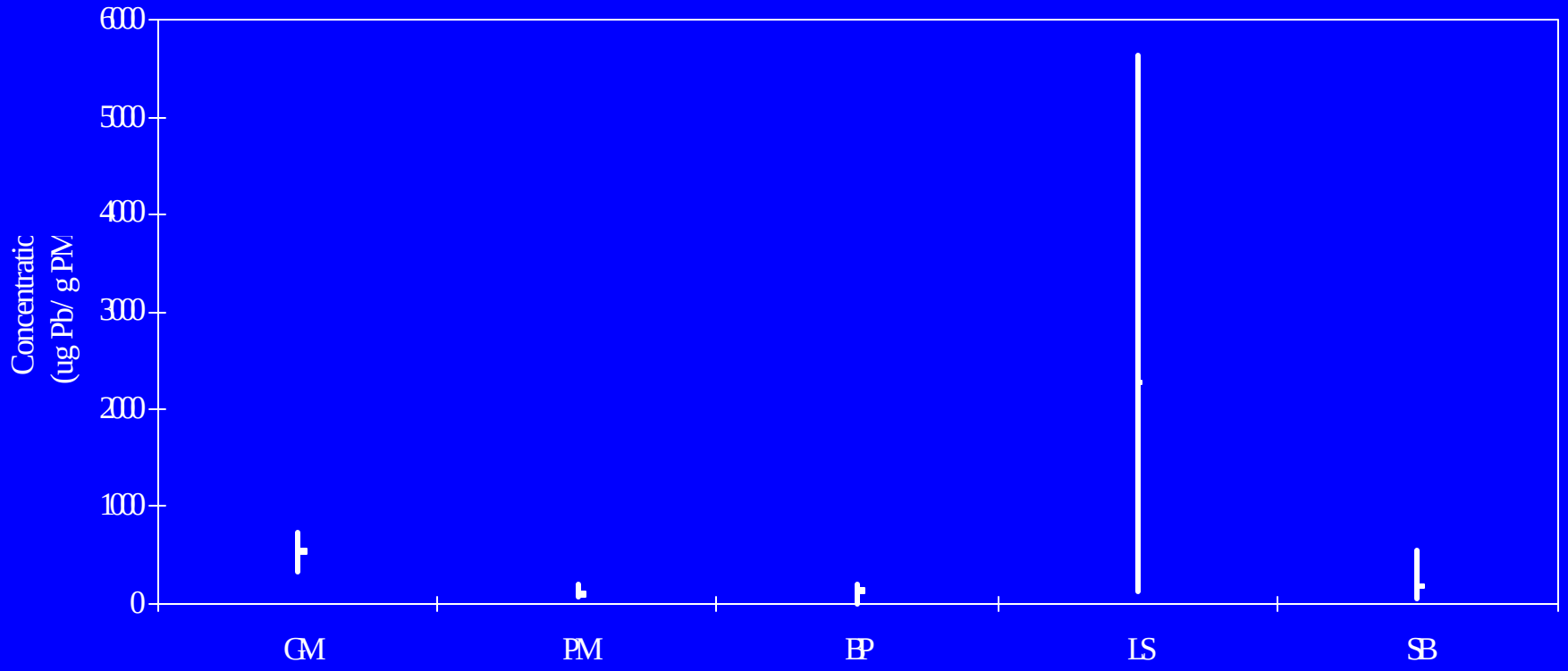
Mass-Weighted PM_{10} Yield



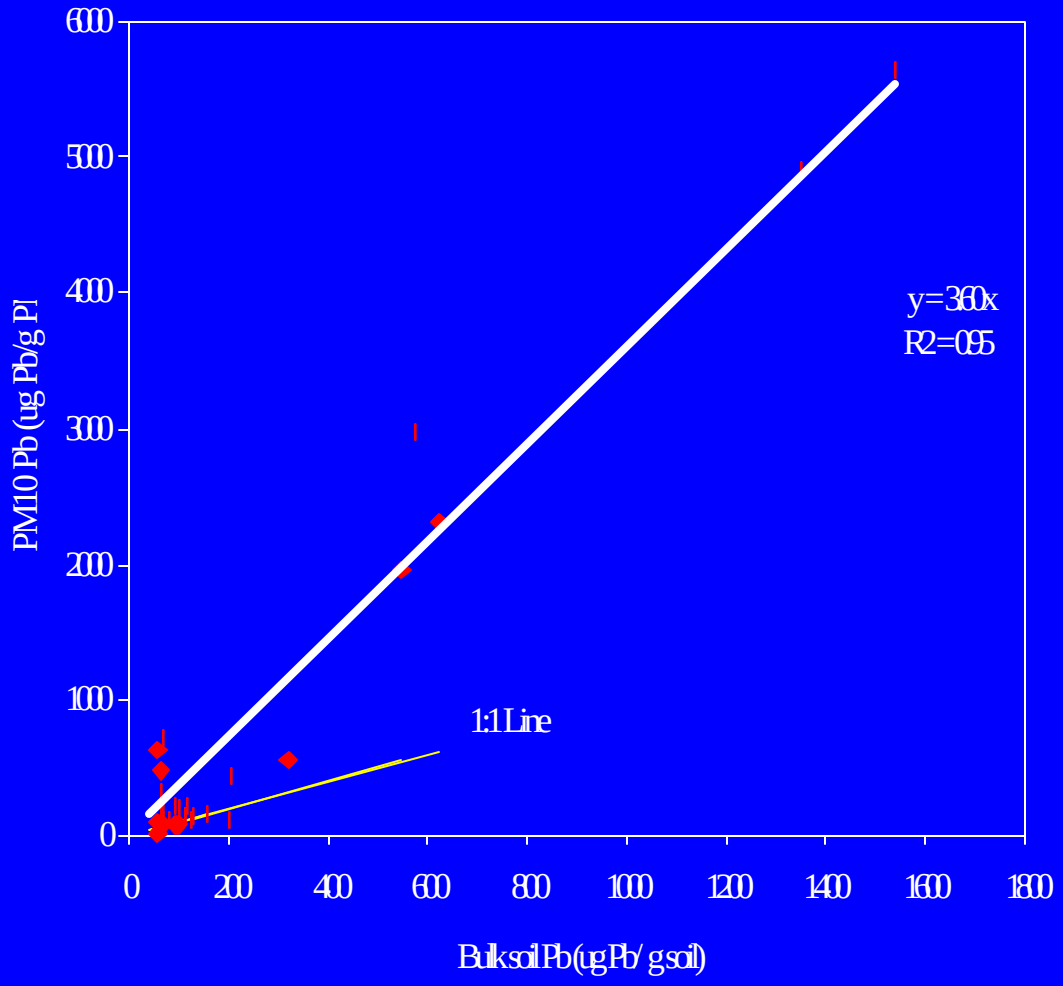
Bias in Fractional PM_{10} Yields



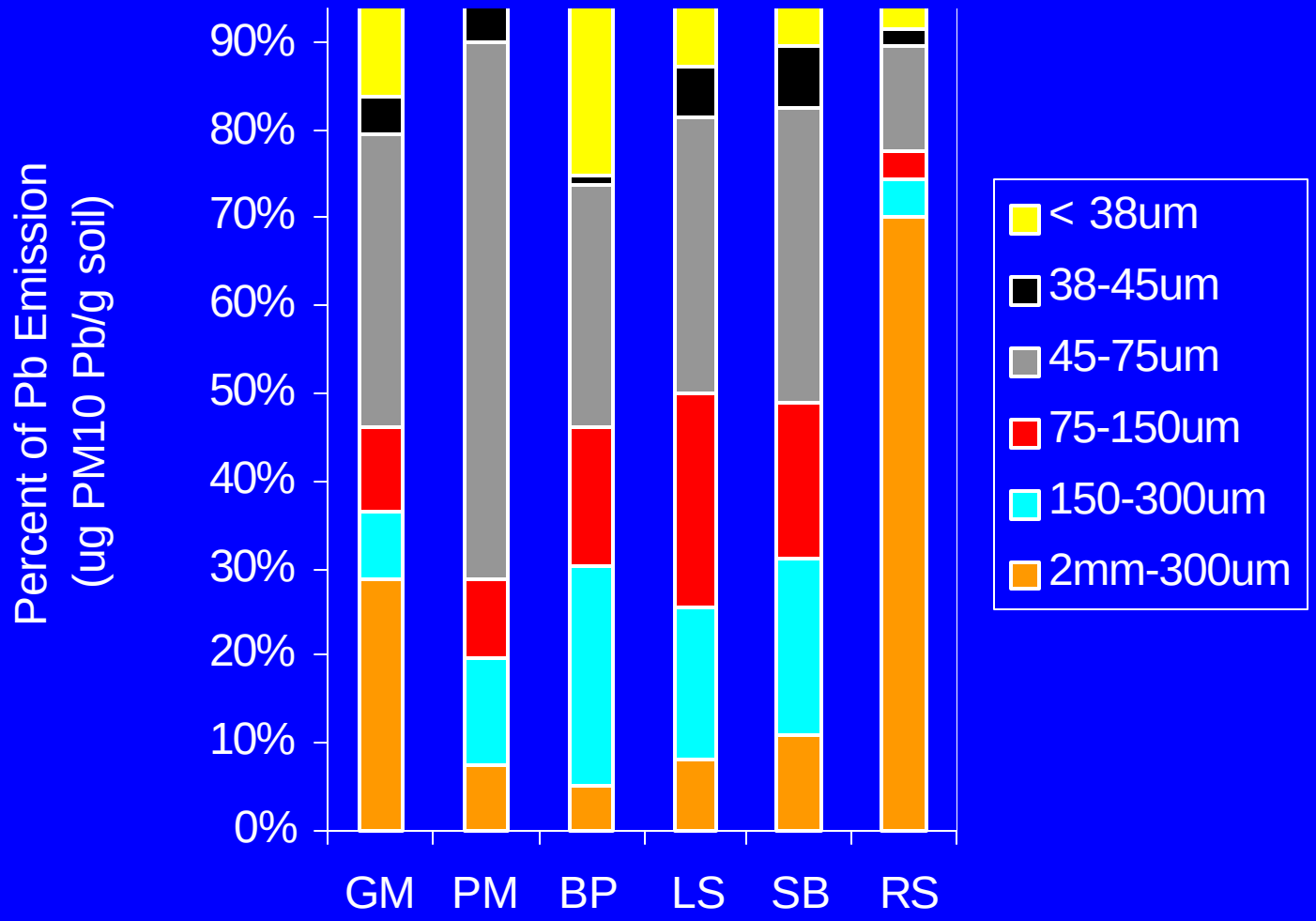
PM_{10} Pb Concentration by Site



Comparing Pb in PM_{10} to Source Soil



Contribution of Size Fractions to Pb Emissions



Enrichment Factor Comparison

	K	Ca	Ti	Rb	Sr	Pb	Zn	Cu	Mn
GM	0.75	0.96	1.03	2.18	2.14	13.9	3.67	18.8	
PM	2.14	1.29	0.81	6.44	0.98	13.2	6.83	63.5	5.67
BP	0.85	0.98	1.14	2.15	1.20	5.36	2.01	13.2	
LS	0.55	1.32	0.92	1.25	0.92	88.7	1.14	5.23	
SB	0.99	0.94	1.69	3.08	1.33	16.5	11.0		
RS	1.12	1.06	0.78	6.54	2.28	31.6	14.0	37.1	
Stockton, CA (1)	0.47	1.30	0.74		1.78	2.75	0.75	2.60	1.13
San Gabriel foothills, CA	0.82	1.04	1.14			5.80		3.67	1.91
Pasadena, CA (2)	1.23	1.83	1.07			8.70		3.15	2.07
Jersey City, NJ (3)	0.86	1.00	1.23		0.74	91.1	3.93	31.2	0.97
Fresno, CA paved road	0.79	1.73	0.71		4.67	76.7	7.47	5.24	1.12
Bakersfield, CA unpave	0.79	0.87	0.68		1.16	2.24	0.74	1.12	0.95
Taft, CA unpaved road (	1.07	1.39	0.76		2.33	12.1	2.07	2.02	0.99

(1) Chow et al., 1992
(2) Miller et al., 1972
(3) Adgate et al., 1998
(4) Hopke, 1985

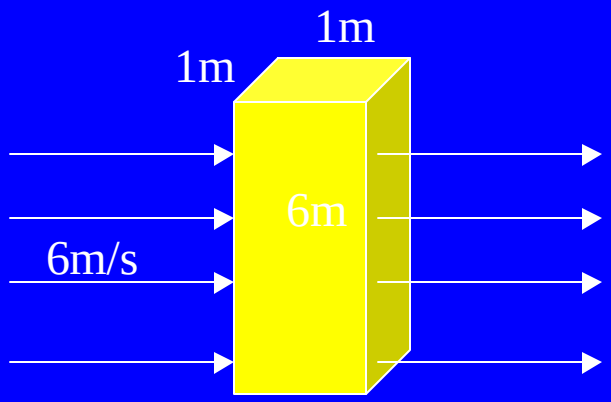
Source Profile Information

Glass Manufacturing	Cl	0.92 **
Perlite Mining	Cl	0.67 *
	Zn	0.54 *
	Br	0.58 *
Borax Processing	Zn	0.69 **
	Se	0.99 *
Lead Smelter	S	0.90 **
	Ga	0.97 **
	Y	0.96 **
Sandblasting	K	-0.75 **
	As	0.81 **
	Rb	-0.63 **

- Linear correlation coefficients between Pb and other 18 elements measured in PM_{10} for each site
- Correlation coefficients significant at either 99.0 (*) or 99.9% (**) listed

Estimating Airborne Pb Levels
Soil Erosion Analysis

- Measured erosion of 374 kg/m over 200m (Fryear et al., 1991)
- Assume:
  - dry soil, smooth bare surface
  - Particles well mixed over 6m height
  - Average wind velocity 6m/s
  - PM_{10} released completely from airborne soils
  - Use average PM_{10} Pb emission for smelter site



$$\frac{(374\text{kg})\left(1.23\ \text{mg PM}_{10}\ \text{Pb}/\text{kg}\right)}{(6\text{h})(3600\ \text{s}/\text{h})(6\ \text{m}/\text{s})(6\text{m}^2)}$$

$$512\ \frac{\text{ng PM}_{10}\ \text{Pb}}{\text{m}^3} \approx 1\ \frac{\text{ìg TSP Pb}}{\text{m}^3}$$

Estimating Airborne Pb Levels
Resuspension Analysis

- Resuspension Factor

  $K=C_A\ (\mu g/m^3)/S(\mu g/m^2)$
- Assume
  - Mixing depth 1mm for wind and 1cm for mechanical
  - Soil 1.6 g/cm^3
  - Average smelter Pb concentration

- Measured Values
  - Wind: 10^{-10} to 10^{-4} m^{-1} (Nicholson, 1988)
  - Mechanical: 10^{-8} to 10^{-2} m^{-1} (Nicholson, 1988)
  - f(t): 10^{-5} to 10^{-9} m^{-1} (Garger et al., 1997)

$$\text{Mechanical: } \left(622\ {}^{mg}/_{kg}\right)\left(1600\ {}^{kg}/_{m^3}\right)(0.01m)\left(10^{-5}\,m^{-1}\right)=100\ {}^{mg}/_{m^3}$$

$$\text{Wind: } \left(622\ {}^{mg}/_{kg}\right)\left(1600\ {}^{kg}/_{m^3}\right)(0.01m)\left(10^{-7}\,m^{-1}\right)=1\ {}^{mg}/_{m^3}$$

Conclusions

- PM_{10} yields averaged 0.6 mg/g
- The average Pb enrichment factor was 3.6
- Estimated “worst-case” airborne concentrations from wind or mechanical erosion were 1 to 100 $\mu g/m^3$
- Contaminated soils may be a significant contributor to airborne Pb under a narrow range of conditions

Acknowledgments

- Lowell Ashbaugh, Deo Heeraman, Gorkem Sirin
- Funding from California Air Resources Board