450R81103

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PRELIMINARY INTERPRETATION OF INHALABLE PARTICULATE NETWORK DATA

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For Presentation at the 74th Annual Meeting of the Air Pollution Control Association

Philadelphia, Pennsylvania June 21-26, 1981

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Introduction

The U.S. Environmental Protection Agency initiated a national sampling network in 1979 to gather size specific particulate data in support of the upcoming review and potential revisions to the National Ambient Air Quality Standard for Particulate Matter.[1] The U.S. EPA is investigating Inhalable Particulates (IP) as one possible size fraction to be regulated under a revised standard.[2] The purpose of this paper is to provide a summary and preliminary interpretation of data from the sampling program of the National Inhalable Particulate (IP) Network.

The sites were selected by the U.S. EPA Regional Offices, States and local agencies, and the Office of Air Quality Planning and Standards to be representative of the air quality in major urban areas and areas of high Total Suspended Particulate matter (TSP) concentration in the United States. They were set up by the Environmental Monitoring Systems Laboratory (EMSL) in cooperation with State and local agencies. EMSL provides preweighed filters to the local agencies or operators who calibrate, operate and maintain the samplers. The exposed filters are returned to EMSL for gravimetric and elemental analysis, data processing and data validation. The network has gradually become operational since 1979 and, as of March 1981, approximately 145 stations are established.

Monitoring System

The instrumentation located at IP network sites monitors particulate matter concentrations in three size ranges: Total Suspended Particulate (TSP) - generally considered less than about 30 μm aerodynamic diameter,[3] Inhalable Particulate (IP) - less than 15 μm, and Fine Particulate (FP) - less than 2.5 μm. The samples are taken every sixth day, except in special studies where more frequent sampling is accomplished. Table I summarizes pertinent information about the samplers used in the network.

As shown in the table, a regular hi-volume sampler was used to measure TSP in the network. This sampler is presently designated as the Federal Reference Method for particulate matter ambient sampling.[4] Various problems associated with the representativeness of the hi-vol have been reported.[5,6,7] These include windspeed and direction dependence, settling of particles on the filter in the off-mode, and formation of artifact sulfate and nitrate on the glass fiber filter.

A dichotomous sampler is used to collect IP.[8] Several problems have been reported in its operation. A virtual impactor separates the IP into two fractions - 2.5 to 15 μm coarse particulate (CP) and <2.5 μm fine particulate (FP), each collected on Teflon filters. The inlet of the sampler theoretically excludes particles larger than 15 μm but, in fact, the size cutoff is somewhat dependent on windspeed.[9] An additional problem recently reported is the loss of coarse particulate from the surface of the Teflon filter during handling.[10] The combined concentrations on the two filters are reported as the total IP mass. Most sites have manually operated samplers which are set up to sample every sixth day. In laboratory tests, the dichotomous sampler has been shown to be relatively imprecise at the lower concentration ranges. This is due to the high tare weight and low quantity of mass collected. Fortunately, the precision is better at the higher concentrations.

Another sampler which is usually collocated with the dichotomous sampler is the Size Selective Inlet Hi Vol (SSI).[11] The SSI sampler incorporates a special inlet to provide an upper cutpoint of 15 μm. This inlet is situated on a regular hi-vol frame and particles are collected on a glass fiber filter identical to that used in the TSP hi-vol. The collection efficiency of the SSI is not influenced by the wind direction, since its inlet is round. Further, windtunnel tests have shown that windspeed dependency problems have been minimized. However, formation of artifact sulfate and nitrate on the glass fiber substrate, due to adsorption of sulfur and nitrogen oxide gases on the filter, is a problem.[7]

Mass concentrations measured by collocated SSI and dichotomous samplers typically differ by an average of 10-15%, with the SSI normally recording higher concentrations. Efforts are underway to more fully characterize and reduce these biases. The EMSL has a program underway to provide quality assurance and chemical analysis of the samples. The chemical analysis may provide clues about the differences in mass collected. However, sufficient chemical analysis data is not yet available for interpretation. For consistency, until the reasons for the biases are clarified, only dichotomous sampler data will be discussed in this paper.

Spatial Distributions

Data collected by the IP Sampling Network presents several opportunities for the examination of spatial distributions of Inhalable and Fine Particulate on regional, urban and neighborhood scales.[12] The Network's widespread geographical location of samplers allows concentrations from various urban areas in the United States to be compared and regional patterns to be discerned. Availability of data from three or more sites in the environs of Birmingham, AL, Los Angeles, CA, San Francisco, CA, Buffalo, NY, and Philadelphia, PA provides insight into urban scale spatial distributions of particulate matter. The special study of the Bridesburg Industrial area of Philadelphia provides similar insight into spatial distributions on the neighborhood scale.

National Urban IP and FP Concentrations

Table II contains the arithmetic average concentrations of TSP, IP and FP at sites in the IP network for a full year of monitoring beginning on October 1, 1979 and ending on September 30, 1980. Each quarter's values have been averaged separately to reveal the seasonal distribution. Only averages containing more than five values have been included. The annual arithmetic mean was calculated as the average of the four quarterly averages rather than from the entire set of data for that year. Early in the network operations, many samples were lost due to startup problems, resulting in a nonuniform distribution of valid sample size among quarters. This averaging procedure gives each season equal weight in determining the annual mean, regardless of the number of samples in each quarter. Also presented in Table II are the maximum concentrations of TSP, IP and FP found during each season. Only maxima from quarters with more than five IP/FP data pairs were chosen. The annual maxima are the highest values which occurred in any one of these quarters. An inspection of these tables yields the typical concentrations and spatial distributions of IP and FP.

Table II illustrates the range in concentrations in urban areas nationwide, arranged by geographic areas. At those sites for which annual arithmetic averages are calculated, the highest average IP concentrations are found in Los Angeles (92 $\mu g/m^3$), El Paso (68 $\mu g/m^3$), Buffalo (63 $\mu g/m^3$), and Birmingham (58 $\mu g/m^3$). There is no clear regional pattern but a wide variability in concentrations among urban areas is seen. The average of FP at urban sites ranges from 13 $\mu g/m^3$ in San Francisco (Richmond) to 37 $\mu g/m^3$ in Los Angeles. The regional distribution of these annual averages is fairly homogeneous in the Eastern United States, ranging from 22 $\mu g/m^3$ in Birmingham to 32 $\mu g/m^3$ in Philadelphia. Average fines concentrations west of the Mississippi River are generally lower, with the exception of El Paso and Los Angeles. This suggests the possibility of a regional scale influence in the east, due to either emissions or meteorology.

Maximum 24-hour concentrations of IP vary substantially and rarely occur on the same day at nearby sites. They appear to be more affected by local than regional phenomena. The spatial variability of these maxima in the west seems comparable to the spatial variability in the east. These maxima range from 51 $\mu g/m^3$ in San Francisco (Richmond) to 146 $\mu g/m^3$ in Philadelphia for IP. In contrast, the FP maxima varied from 37 $\mu g/m^3$ in Birmingham to 128 $\mu g/m^3$ in Philadelphia. The FP/IP ratio for the max days was compared to gain insight into the causes of high IP concentrations. It is important to note that the ratio of the maximum FP to maximum IP concentration at each site is generally high, averaging about 70%. In many cases, these maxima occurred on the same day. This suggests that many of the highest IP concentrations may be due to high FP concentrations. A notable exception to this is El Paso, Texas.

Regional Scale Particulate Matter Patterns

The regional scale pattern of particulate matter is a measure of large scale phenomena that are not affected by specific sources or localized groups of sources. Ideally, these sites would be located in remote areas, but in practice they are in nonurban locations which are influenced somewhat by the "urban plume" from nearby urban areas. Eight sites in the IP network are located near, but outside of, urban areas and have sufficient data to be useful in estimating large scale particulate concentrations.

Table III gives a summary of data from these sites. From this table, quarterly IP concentrations typically average from a low of 16 $\mu g/m^3$ at Pearl City, HI to a high of 63 $\mu g/m^3$ in the rural area around El Paso, Texas. The Hawaii site is influenced only by the local island activity and sea salt and would probably represent a near minimum for any U.S. location. The El Paso nonurban site is affected by dust storm, agricultural activity and appears to be atypically high, even for a desert agricultural area. The other regional scale sites generally are in the 20-35 $\mu g/m^3$ range.

FP annual average concentrations in Table III reported for the western sites are generally averaged from 6-13 $\mu g/m^3$ at four sites. In contrast, average concentrations range from 15 to 23 $\mu g/m^3$ at four sites in the eastern part of the country. Thus, a regional doubling of FP concentrations is seen when comparing the East to the West. It is suggested that this might be due to sulfate concentrations which are generally higher in the East. Chemical data from the network, when available, can be used to confirm this.

Urban Scale Particulate Matter Patterns

The IP and FP concentrations nationwide were shown to be substantially different among urban areas. It is not apparent thus far whether these same differences are apparent within an urban area. This can be investigated by looking more closely at data within urban areas to see if similar variations in concentrations occur. This will offer clues to the spatial representativeness of IP and FP concentrations. Table IV compares IP and FP concentrations in five urban areas.

The annual averages for IP at urban or suburban sites range from 40 to 58 $\mu g/m^3$ in Birmingham, from 25 to 42 $\mu g/m^3$ in the San Francisco Bay area, from 52 to 63 $\mu g/m^3$ in Buffalo, from 46 to 92 $\mu g/m^3$ in the Los Angeles area, and from 37 to 48 $\mu g/m^3$ in Philadelphia. These ranges within airsheds are comparable to those among airsheds found earlier. A similar large range exists for maximum daily values of IP at urban scale sites, which is also comparable to the range of IP maxima among cities. This variability within an urban area suggests that localized sources may be major contributors to high IP concentrations.

Annual averages of FP are more uniform for urban and suburban sites within an airshed, ranging from 22 to 32 $\mu g/m^3$ in Birmingham, 13 to 18 $\mu g/m^3$ in San Francisco, 27 to 33 $\mu g/m^3$ in Buffalo, 25 to 37 $\mu g/m^3$ in Los Angeles, and 23 to 32 $\mu g/m^3$ in Philadelphia. FP maxima for these same airsheds varies from 39 to 52 $\mu g/m^3$ in Birmingham, 39 to 82 $\mu g/m^3$ in San Francisco, 58 to 70 $\mu g/m^3$ in Buffalo, 92 to 109 $\mu g/m^3$ in Los Angeles, and 99 to 128 $\mu g/m^3$ in Philadelphia. The lower degree of uniformity in the IP compared to FP concentrations in urban areas suggests that a larger portion of IP may be due to local sources. Chemical data, when available, may help to confirm this.

Industrial Neighborhood Scale Particulate Matter Patterns

In an effort to understand more fully the spatial patterns within and around a heavily industrialized area, the Bridesburg industrial area of Philadelphia was the subject of an intensive sampling effort from October 3, 1979 to February 15, 1980. Seven sampling sites were located within a 2 km x 4 km area. Three sites within the core of this area were in the industrial area and four other sites were on the perimeter. A fifth site, N.E. Airport, was located approximately 10 km away to the northeast at a small airport in a less densely populated area in a generally downwind direction. At each site, a TSP hi-vol and a dichotomous sampler were operated for 24 hour periods. This study is described more elsewhere.[13,14]

Figure 1 compares the average and range of concentrations of TSP, IP and FP within the industrial, perimeter and N.E. Airport subgroupings as a function of distance from the industrial area. The ranges show substantial variability within each classification, but there are major differences between the industrial, perimeter and airport groupings.

TSP and IP are 45%, and 31% higher at industrial sites when compared to perimeter sites. Absolute concentration differences are 30 $\mu g/m^3$ for TSP, and 16 $\mu g/m^3$ for IP. These differences occur over an average distance between sites of 1 km. It is apparent that TSP and IP concentrations are substantially heterogeneous over a very small area. From the

study area to the N.E. airport, a distance of 10 km, an additional average concentration decrease of 25 $\mu g/m^3$ for TSP and 17 $\mu g/m^3$ for IP was seen.

A similar decrease was not observed for FP between the industrial and perimeter sites. In fact, with one exception, the FP sites in the Bridesburg study area all exhibited a rather flat profile. There was a substantial decrease in FP levels between the industrial area and the N.E. Airport site, indicating that an average of 8 to 10 $\mu g/m^3$ of fine particles was associated by sources in or near the industrial study area. This industrial scale study is described in more detail elsewhere.[14]

Seasonal Patterns

The IP network offers the opportunity to evaluate seasonal patterns in various urban areas and regions of the country. All samples are of 24-hour duration, which precludes examination of the hourly variability, and the sixth day sampling schedule (third day at some sites) does not provide a strong data base for investigating daily distributions or weekday/weekend patterns. Special studies are being conducted for these purposes.

Seasonal patterns of average and maximum IP and FP concentrations are examined by reading across a row of Table II for a specific sampling site. Trijonis,[15] studied the St. Louis regional monitoring data and concluded that IP and FP concentrations peak in the summertime. This hypothesis will be evaluated in other parts of the country.

Figure 2 shows the seasonal variation in average quarterly concentrations for IP and FP in 11 eastern and midwest cities. This geographical subset of sites was selected because of the regional patterns shown above for FP concentrations. There is a slight increase in FP in the summer, which causes IP to be higher, although the increase is only 7 $\mu g/m^3$ over the fall-winter-spring averages. The ranges appear to be generally similar among the quarters, except that FP seems less variable in both spring and fall. Figure 3 shows the seasonal variation in quarterly maxima. FP is seen to be lower in the spring. The CP fraction can be observed in these figures as the difference in FP and IP levels. It is interesting that in the spring the FP/CP ratio is lower than in the other seasons, suggesting a different mix of sources of IP in the spring.

The data suggests that FP might be slightly lower in the spring season and higher in the summer, causing IP to be slightly higher in the summer. However, there is not sufficient evidence to suggest that there is a general nationwide seasonal pattern in IP or FP, as was suggested in the earlier St. Louis work.

Conclusions

Typical annual average urban IP concentrations ranged from 40-50 $\mu g/m^3$ with several areas averaging 60 to 90 $\mu g/m^3$. Quarterly maximum values were typically around 100 $\mu g/m^3$, with a few as high as 200 $\mu g/m^3$. FP typically averaged 20 to 30 $\mu g/m^3$ in the East, generally lower in the West, with the highest average of 37 $\mu g/m^3$ in the Los Angeles area. FP quarterly maxima averaged 50 to 60 $\mu g/m^3$ with a few sites having maxima slightly over 100 $\mu g/m^3$.

Examination of IP and FP data on a neighborhood and urban scale suggests that Inhalable Particulate is strongly influenced by local sources. Concentration changes averaging 16 $\mu g/m^3$, or 31%, were found between sites separated by as little as 1 km distance. FP averages were generally more homogeneous, although some local influence on both average and 24-hour values was apparent. A regional pattern of FP was apparent with concentrations at Eastern regional-scale sites double those of Western sites.

There appeared to be no strong seasonal variation of IP and FP averages and maxima. Slightly higher concentrations were found in the summer, and slightly lower in the spring for FP when looking at the Eastern region of the United States. This causes IP to be slightly higher in the summer.

NOTE TO EDITORS

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Table I. Comparison of IP Network Sampling Instrumentation

Instrument	Size Fractions	Filter Used	Airflow Rate	Designation
Hi volume sampler	$< \sim 30\mu m$	Glass fibre	40 CFM	TSP
Size Selective Hi volume sampler	$< 15\mu m$	Glass fibre	40 CFM	IP[a]
Dichotmous sampler	$< 2.5\mu m$	Teflon	15 LPM	FP
	2.5-15 μm	Teflon	1.67 LPM	CP
	$< 15\mu m$	Sum of above	16.7 LPM[b]	IP

[a] No SSI-IP data presented

[b] Approximately 1 CFH

Table III. Fine and Inhalable Particulate Matter Concentrations at Regional Sites (FP/IP), $\mu g/m^3$

Geographic Area	Fall 1979	Winter 1980	Spring 1980	Summer 1980	Average
West					
HI Pearl City	8/14	14/22	7/16	5/13	9/16
NV Winnemucca	8/33	5/23	5/28	-/-	6/28
OR Columbia County	16/31	-/19	9/37	15/43	13/33
TX El Paso	12/68	10/51	15/74	13/59	13/63
East					
IL Will County	15/30	27/40	22/34	16/32	20/34
NC Res Tri Park	22/26	17/20	17/23	37/43	23/28
TX Houston Area	16/42	14/28	12/23	16/34	15/32
NY Erie County	17/21	14/19	18/24	-/-	16/21

- missing data

Table II. Quarterly Averages and Maxima of TSP, IP nd FP in U.S. Urban Areas

City	Quarterly Averages					Quarterly Maxima				
	Fall 1979	Winter 1980	Spring 1980	Summer 1980	Annual	Fall 1979	Winter 1980	Spring 1980	Summer 1980	Annual
Northeast										
Hartford, CT										
Hartford		53/41/22	62/34/16	69/41/25			103/131/106	93/50/30	95/68/44)	
Washington, DC										
Washington	59/36/23	66/42/27	84/33/19			126/86/48	90/85/72	128/39/35		
Pittsburgh, PA										
Hazelwood	-/68/37	-/59/34				-/154/79	-/85/48			
Philadelphia, PA										
500 S. Broad	57/44/26	53/-/-	70/42/22			179/117/69	96/-/-	123/78/39		
Allegheny	106/58/24	128/61/25				200/134/82	226/113/49			
N.E. Airport	42/34/24	35/33/21	53/35/19	65/45/28	49/37/23	113/134/90	77/70/47	84/60/39	137/134/99	137/134/99
Pres. Home	48/43/28	43/51/39	62/48/28	76/50/31	57/48/32	161/146/112	73/136/128	94/67/43	149/113/88	161/146/128
St. John's	59/53/33	55/42/26				200/149/101	98/64/42			
Baltimore, MD										
Baltimore		-/48/27					-/94/50			
Boston, MA										
Boston		62/35/20		83/49/31			93/54/41		102/76/55	
E. Boston		44/33/19	61/32/16	65/41/26			81/69/47	80/40/21	97/65/49	
Buffalo, NY										
P.S. 26	63/56/29	82/72/33	98/62/31	104/60/40	87/63/33	133/114/55	165/134/56	160/110/56	150/95/70	165/138/70
P.S. 28	78/50/24	92/51/27	114/53/28	109/53/28	98/52/27	144/80/38	152/111/54	191/94/47	163/95/58	191/111/58
Wilmuth		133/40/23					222/122/35			
Midwest										
Minneapolis, MN										
Minneapolis A	33/25/14	44/30/18	72/37/14	55/27/11	51/34/14	62/42/27	98/55/44	126/61/21	85/49/21	126/61/44
Minneapolis B	53/37/16	65/43/23	91/45/15	94/44/15	76/42/17	98/55/29	99/63/47	183/82/22	221/105/29	221/105/47
St. Louis, MO										
Affton		63/31/21	90/40/19	79/59/27			94/56/39	137/63/40	118/85/48	
Akron, OH										
Morley Health	61/42/23	62/49/27	80/47/23	81/56/32	71/43/26	109/84/47	121/95/48	117/77/43	114/81/55	121/95/55
Cincinnati, OH										
Cincinnati	48/33/22	42/40/26	59/39/22	68/51/37	54/41/27	88/69/47	68/64/45	114/64/37	121/83/73	121/83/73

Table II. Quarterly Averages and Maxima of TSP, IP nd FP in U.S. Urban Areas (Continued)

City	Quarterly Averages					Quarterly Maxima				
	Fall 1979	Winter 1980	Spring 1980	Summer 1980	Annual	Fall 1979	Winter 1980	Spring 1980	Summer 1980	Annual
Steubenville, OH										
Washington Sch.	113/71/45	99/58/38				223/134/85	192/129/64			
Kansas City										
Kansas		86/45/34	111/52/29	114/56/19			114/60/50	168/72/48	179/90/33	
Missouri		97/54/25	109/58/19	90/46/15			155/67/44	160/92/34	117/57/20	
South										
Birmingham, AL										
S. Birmingham	52/35/21	40/30/18	75/49/28	83/46/29	63/40/24	73/56/35	60/45/30	110/75/48	120/68/46	120/74/48
N. Birmingham	88/36/26			150/80/37		192/79/50			237/134/55	
Inglenook	103/43/26	87/44/19	136/68/28	120/63/31	112/55/26	313/102/52	176/71/30	299/140/41	177/90/45	313/140/52
Mtn. Brook	-/28/15	36/23/15	58/33/21	64/34/24	-/30/22	-/65/24	59/32/25	82/46/36	91/55/37	-/65/37
Tarrant City	83/40/28	91/35/21	133/79/43	148/78/34	114/58/32	145/79/48	190/68/38	174/47/26	211/110/49	211/110/49
Dallas, TX										
Dallas		114/37/26	76/32/22	74/39/16			474/88/62	111/60/46	90/58/33	
Southwest										
El Paso, TX										
Tillman	155/92/31	103/-/-	111/67/30	108/46/12	[a]125/68/25	320/231/61	227/-/-	208/81/24	211/86/23	325/213/61
West Coast										
Los Angeles, CA										
Azusa	115/68/30	77/38/16				168/115/69	125/62/29			
West LA	77/60/36	68/38/21	77/43/18	68/42/23	73/46/25	146/99/72	97/80/60	113/66/30	125/80/58	125/99/92
Pasadena	98/74/40	35/41/24				169/118/76	35/78/54			
Rubidoux	163/106/48	72/47/17	136/96/39	206/119/42	61/92/37	250/171/109	181/99/52	231/156/69	392/200/106	250/200/109
San Francisco, CA										
Livermore	-/60/15	50/40/18	63/28/10	79/39/15	-/42/15	-/139/34	81/72/50	95/47/16	103/87/60	-/87/60
Richmond	48/30/17	46/31/21	53/21/7	47/17/7	49/25/13	102/51/39	69/81/71	73/29/10	85/41/13	102/51/39
S.F. East		64/44/29		45/23/9			101/84/59		87/51/17	
San Jose	93/47/24	73/39/23	64/24/9	85/31/14	79/35/18	269/106/76	139/113/82	82/40/5	129/51/23	269/113/82
Seattle, WA										
Seattle Light	41/24/14	41/28/18	36/20/9	39/23/11	39/24/14	90/58/51	71/51/34	74/36/17	56/32/24	90/58/51

Each entry contains mass concentrations in $\mu g/m^3$ according to the following format: TSP/IP/FP

[a]Average of three quarter's data.

Table IV. Range of IP and FP Concentrations at Various Sites in Several Urban Areas, $\mu g/m^3$

	INHALABLE PARTICULATE		FINE PARTICULATE	
Area	Annual Average	Site Maxima	Annual Average	Site Maxima
Birmingham	40-58	65-140	22-32	37-52
San Francisco	25-42	51-113	13-18	39-82
Buffalo	52-63	111-138	27-33	58-70
Los Angeles	46-92	99-200	25-37	92-109
Philadelphia	37-48	134-146	23-32	99-128
Average High/Low Ratio	1.53	1.74	1.39	1.44

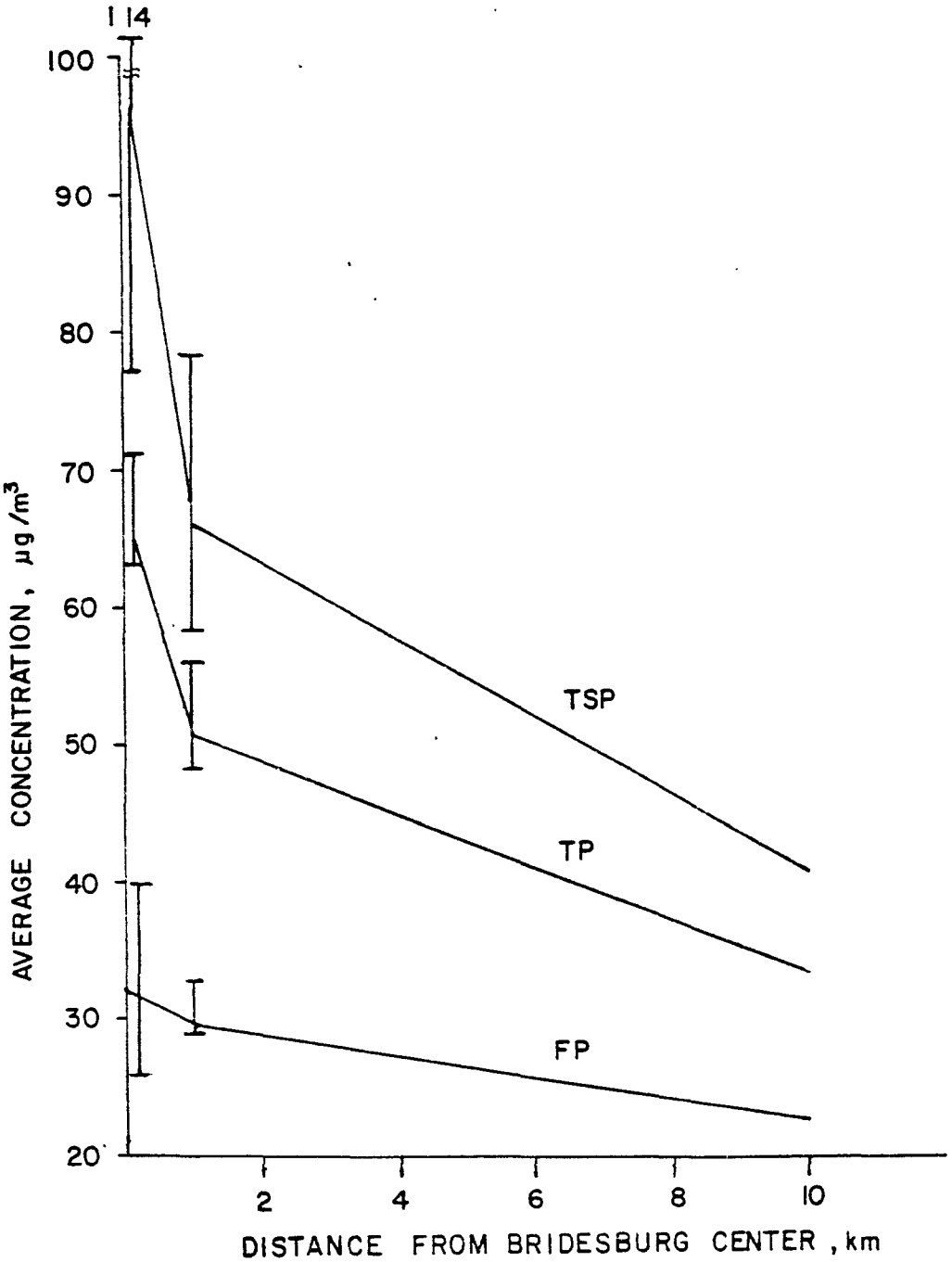

Figure 1. Average concentrations and concentration ranges in Bridesburg area versus distance between sites for TSP, IP and FP $\mu g/m^3$

Replacement for Figures 2 and 3
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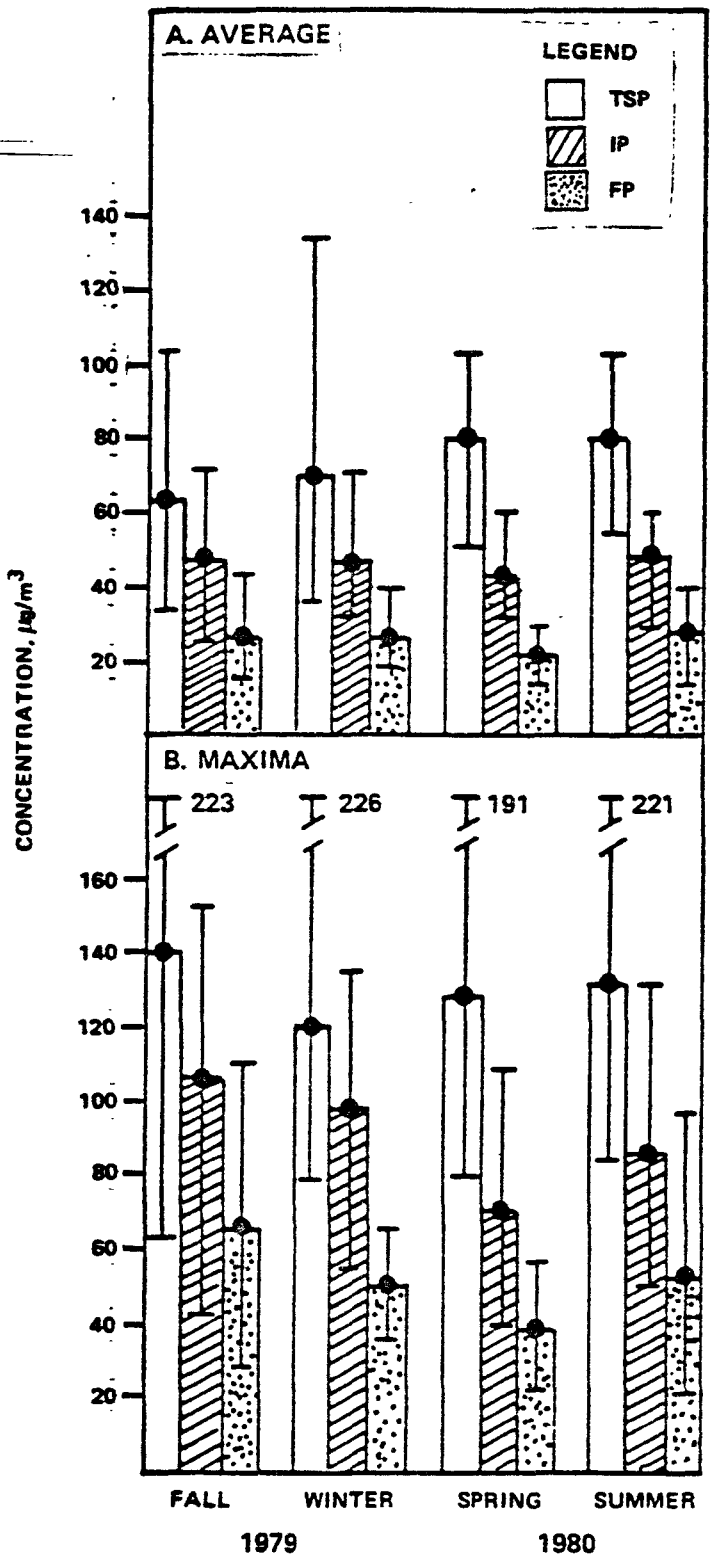

Figure 2. Seasonal variation of quarterly average FP and IP in 11 Eastern and Midwestern U.S. urban areas.

Figure 3. Seasonal variation of quarterly maxima FP and IP in 11 Eastern and Midwestern U.S. urban areas

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Table II. Quarterly Averages and Maxima of TSP, IP nd FP in U.S. Urban Areas

City	Quarterly Averages					Quarterly Maxima				
	Fall 1979	Winter 1980	Spring 1980	Summer 1980	Annual	Fall 1979	Winter 1980	Spring 1980	Summer 1980	Annual
Northeast										
Hartford, CT										
Hartford		53/41/22	62/34/16	69/41/25			131/103/59	93/53/33	95/68/44	
Washington, DC										
Washington	59/36/23	66/42/27	84/33/19			126/86/48	90/85/72	128/59/35		
Pittsburgh, PA										
Hazelwood	-/68/37	-/59/34				-/154/79	-/85/48			
Philadelphia, PA										
500 S. Broad	57/44/26	53/-/-	70/42/22			179/117/69	96/-/-	123/78/39		
Allegheny	106/58/24	128/61/25				200/134/82	226/113/49			
N.E. Airport	42/34/24	35/33/21	53/35/19	65/45/28	49/37/23	113/134/90	77/70/47	84/60/37	137/134/99	137/134/99
Pres. Home	48/43/28	43/51/39	62/48/28	76/50/31	57/48/32	161/146/112	73/-/-	94/37/43	149/113/88	161/146/112
St. John's	59/53/33	55/42/26				200/149/101	98/64/42			
Baltimore, MD										
Baltimore		-/48/27					-/94/50			
Boston, MA										
Boston		62/35/20		83/49/31			93/54/41		102/76/55	
E. Boston		44/33/19	61/32/16	65/41/26			81/69/47	80/40/21	97/65/49	
Buffalo, NY										
P.S. 26	63/56/29	82/72/33	98/62/31	104/60/40	87/63/33	133/114/55	165/134/56	160/110/56	150/95/70	165/134/70
P.S. 28	78/50/24	92/51/27	114/53/28	109/53/28	98/52/27	144/80/38	152/111/54	191/94/47	163/95/58	191/111/58
Wilmuth		133/40/23					222/122/35			
Midwest										
Minneapolis, MN										
Minneapolis A	33/25/14	44/30/18	72/37/14	55/27/11	51/30/14	62/42/27	98/55/44	126/61/21	85/49/21	126/61/44
Minneapolis B	53/37/16	65/43/23	91/45/15	94/44/15	76/42/17	98/55/29	99/63/47	183/82/22	221/105/31	221/105/47
St. Louis, MO										
Affton		63/31/21	90/40/19	79/59/27			94/56/39	137/63/40	118/85/48	
Akron, OH										
Morley Health	61/42/23	62/49/27	80/47/23	81/56/32	71/43/26	109/84/47	121/95/48	117/77/43	114/81/55	121/95/55
Cincinnati, OH										
Cincinnati	48/33/22	42/40/26	59/39/22	68/51/37	54/41/27	88/69/47	68/64/45	114/64/37	121/83/73	121/83/73

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Table II. Quarterly Averages and Maxima of TSP, IP nd FP in U.S. Urban Areas (Continued)

City	Quarterly Averages					Quarterly Maxima				
	Fall 1979	Winter 1980	Spring 1980	Summer 1980	Annual	Fall 1979	Winter 1980	Spring 1980	Summer 1980	Annual
Steubenville, OH										
Washington Sch.	113/71/45	99/68/38				223/134/85	192/129/64			
Kansas City										
Kansas		86/45/34	111/52/29	114/56/19			114/60/50	168/72/48	179/90/33	
Missouri		97/54/25	109/58/19	90/46/15			155/67/44	160/92/34	117/77/56	
South										
Birmingham, AL										
S. Birmingham	52/35/21	40/30/18	75/49/28	83/46/29	63/40/24	73/56/35	60/45/30	110/75/48	120/68/46	120/75/48
N. Birmingham	88/36/26			150/80/37		192/79/50			237/134/55	
Inglenook	103/43/26	87/44/19	136/68/28	120/63/31	112/55/26	313/102/52	176/71/30	299/140/41	177/90/45	313/140/52
Mtn. Brook	-/28/15	36/23/15	58/33/21	64/34/24	- /30/19	-/65/24	59/32/25	82/46/36	91/55/37	211/110/49
Tarrant City	83/40/28	91/35/21	133/79/43	148/78/34	114/58/32	145/79/48	190/68/38	174/89/42	211/110/49	
Dallas, TX										
Dallas		114/37/26	76/32/22	74/39/16			474/88/62	111/60/46	90/58/33	
Southwest										
El Paso, TX										
Tillman	155/92/31	103/-/-	111/67/30	108/46/12	[a]125/68/25	320/213/61	227/-/-	208/93/24	211/86/23	320/213/61
West Coast										
Los Angeles, CA										
Azusa	115/68/30	77/38/16				168/115/69	125/62/29			
West LA	77/60/36	68/38/21	77/43/18	68/42/23	73/46/25	146/99/72	97/80/60	113/66/30	125/80/58	146/99/72
Pasadena	98/74/40	35/41/24				169/118/76	-/78/54			
Rubidoux	163/106/48	72/47/17	136/96/39	206/119/42	161/92/37	250/171/109	181/99/52	231/156/69	392/200/106	392/200/109
San Francisco, CA										
Livermore	-/60/15	50/40/18	63/28/10	79/39/15	- /42/15	-/139/34	81/72/50	95/47/16	103/87/60	103/87/60
Richmond	48/30/17	46/31/21	53/21/7	47/17/7	49/25/13	102/51/39	69/81/71	73/29/10	85/41/13	102/81/71
S.F. East		64/44/29		45/23/9			101/84/59		121/64/28	
San Jose	93/47/24	73/39/23	64/24/9	85/31/14	79/35/18	269/106/76	139/113/82	82/40/15	129/51/23	269/113/82
Seattle, WA										
Seattle Light	41/24/14	41/28/18	36/20/9	39/23/11	39/24/14	90/58/51	71/51/34	74/38/17	56/32/24	90/58/51

Each entry contains mass concentrations in $\mu g/m^3$ according to the following format: TSP/IP/FP

[a] Average of three quarter's data.