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Field Study to Determine Spatial Variability Of Lead From Roadways

EPA-450/4-83-002

Field Study To Determine Spatial Variability Of Lead From Roadways

by

PEDCo Environmental, Inc.
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Cincinnati, Ohio 45246

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ACKNOWLEDGMENT

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SECTION 1

INTRODUCTION

The United States Environmental Protection Agency (U.S. EPA) promulgated National Ambient Air Quality Standards (NAAQS) for lead on October 5, 1978.[1] Compliance with these standards is determined by measuring the concentrations of lead in the ambient air. In support of the measurement programs, the U.S. EPA is promulgating regulations for selection of appropriate lead monitoring sites. The guidelines specify vertical distances and setback distances from roadways for lead monitoring sites.

The EPA requested PEDCo Environmental to perform a limited field monitoring study to determine horizontal and vertical lead distribution in the area of expected maximum lead concentrations along roadways. The intent was to show relative distributions over specific distance ranges to provide support for the monitor siting ranges specified in the regulations. These ranges are necessary in order to provide monitoring agencies with flexiblity to consider practical factors such as availability of utilities, protection of instruments from vandalism, etc. in monitor siting. While inferences can be drawn from existing studies of lead and total suspended particulate distributions and relationships,[2-7] the previous studies do not address adequately both horizontal and vertical lead concentration distributions within the ranges specified in the guideline. Since the study has a narrowly-defined purpose, it was not designed to provide data for predictive models, for explaining traffic volume and meteorological impact on lead concentrations, for correlation with particle size data, or for similar applications that would require more extensive sampling and experimental design.

SECTION 2

SAMPLING DESIGN

2.1 SITE SELECTION

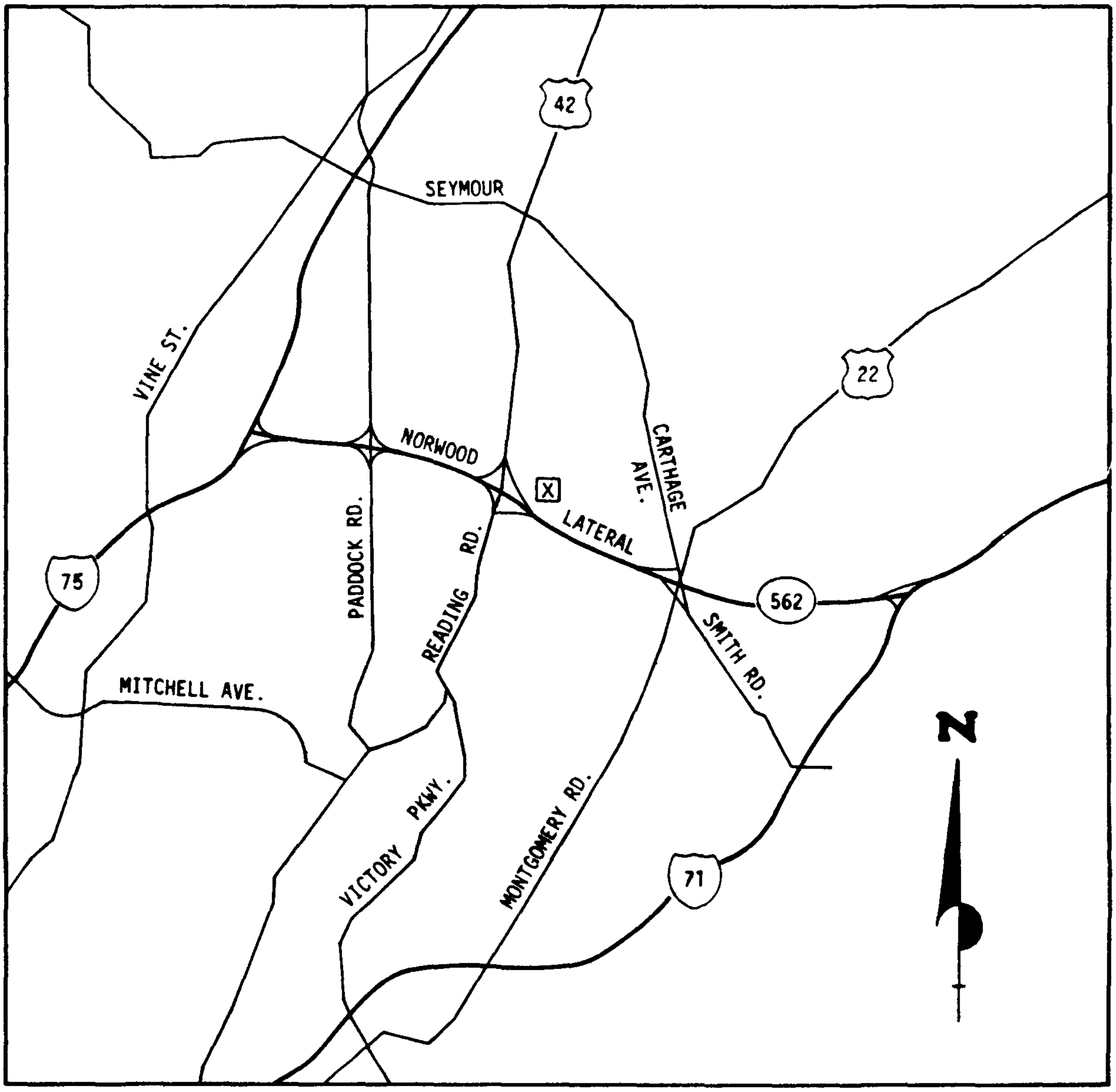
The following criteria were applied in locating an appropriate monitoring site: (1) an average daily vehicle volume of at least 40,000 vehicles, (2) an average vehicle speed of at least 35 to 45 miles per hour, (3) reasonable distance from any topographic obstructions to air flow, and (4) availability of utilities and security for equipment. The site selected for the monitors was the parking area of an abandoned drive-in theatre on State Route 562, also called the Norwood Lateral. This roadway is the major connecting route between Interstate 75 and Interstate 71 in the Norwood area, a few miles north of downtown Cincinnati, as shown in Figure 2-1.

2.2 VEHICLE DENSITY

Information obtained from the City of Cincinnati Traffic Engineer's Office indicates an average of 58,500 vehicles per day in the area of the monitoring site. Figure 2-2 indicates contributions to the total traffic volume at the various entrance and exit ramps; Table 2-1 shows a typical hourly breakdown of traffic volume. The table shows definite peak periods of traffic during the hours of 3 to 5 p.m. and 7 to 8 a.m.

Leaded gasoline is the primary contributor of lead emissions from motor vehicle traffic. The Ohio, Kentucky, Indiana Regional Council of Governments indicated that 62 percent of the vehicle miles traveled in Hamilton County (which encompasses the monitoring area) represent vehicles of model year 1975 or later.*

*Telephone communication with a representative of the Ohio, Kentucky, and Indiana Regional Council of Governments on May 19, 1980.



[X] LOCATION OF SITE

Figure 2-1. Map of Route 562 relative to I-75 and I-71.

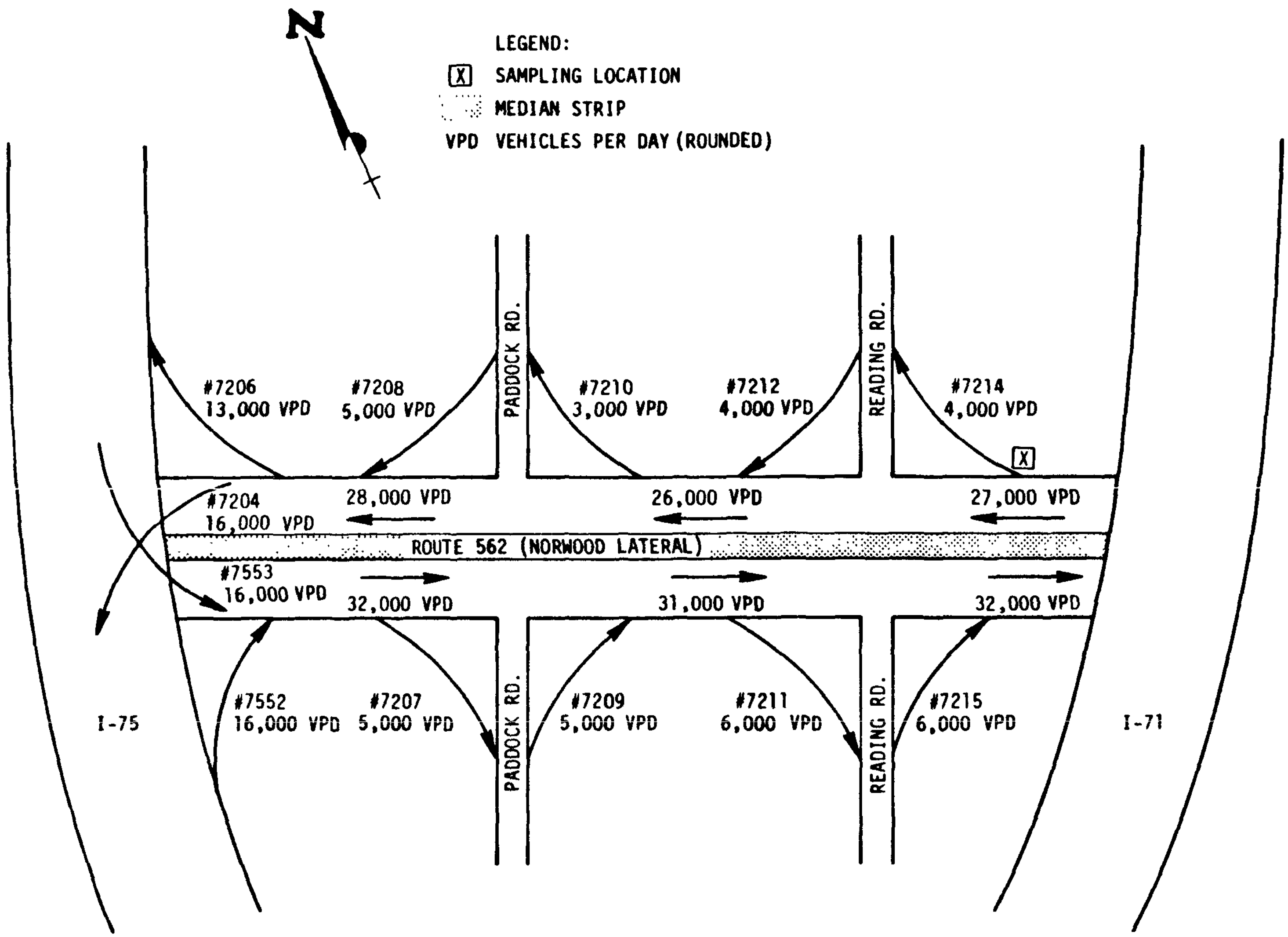


Figure 2-2. Schematic of traffic contributing to Route 562.

TABLE 2-1. TYPICAL ENTRANCE AND EXIT TRAFFIC VOLUME ON ROUTE 562 RAMPS
(Vehicles per hour, 1977 data)

Time	Ramp No.											
	7204 To I-75	7553 From I-75	7552 From I-75	7206 From 562	7207 To Paddock	7208 from Paddock	7209 from Paddock	7210 To Paddock	7215 from Reading	7214 To Reading	7212 from Reading	7211 To Reading
Noon-1 p.m.	762	802	858	680	288	318	230	146	315	262	239	296
1-2 p.m.	760	747	845	638	294	316	274	150	365	228	206	290
2-3 p.m.	909	1016	1112	898	336	336		204		298		329
3-4 p.m.	1221	1218	1192	1045	392	440	442	210	461	421	366	472
4-5 p.m.	1242	1174	1116	1043	380	451	666	206	470	450	449	425
5-6 p.m.	1177	981	1011	960	317	382	468	200	394	329	321	355
6-7 p.m.	872	680	748	606	194	269	199	129	333	207	182	223
7-8 p.m.	687	550	634	418	157	195	179	94	268	201	172	245
8-9 p.m.	560	434	529	338	123	165	123	90	266	135	148	174
9-10 p.m.	598	427	589	400	114	186	105	97	201	115	132	169
10-11 p.m.	511	459	453	293	129	114	78	82	162	111	93	169
11-12 p.m.	455	299	416	416	107	109	93	59	170	88	79	163
Midnight-1 a.m.	346	211	234	193	90	114	67	37	85	44	52	126
1-2 a.m.	195	117	147	146	29	46	49	20	44	16	31	47
2-3 a.m.	142	97	116	111	39	45	26	25	46	14	21	42
3-4 a.m.	73	104	107	83	33	37	25	29	25	12	15	31
4-5 a.m.	102	102	144	67	33	58	28	28	35	20	6	48
5-6 a.m.	245	343	353	193	85	75	43	77	109	40	42	82
6-7 a.m.	702	1010	923	687	301	233	173	285	321	268	142	339
7-8 a.m.	1088	1231	1257	1193	507	309	273	452	372	469	231	488
8-9 a.m.	872	1107	1085	848	431	295	216	267	318	288	200	407
9-10 a.m.	730	832	795	660	264	263	144	150	281	167	176	265
10-11 a.m.	749	823		594	247	259	189	150	282	150	176	263
11-*Noon*	740	812	924	643	271	302	240	157	311	163	213	311

This is significant because, beginning in 1975, most U.S. manufactured light-duty vehicles were designed to operate on lead-free fuel. However, not all vehicles traveling in Hamilton County are U.S.-manufactured or light-duty. Some foreign-manufactured vehicles still burn leaded gasoline; moreover, some heavy-duty vehicles burn leaded gasoline and others burn diesel fuel, which is lead-free. Also, some owners of newer cars may have altered their vehicles so that they can burn the less expensive leaded fuel.

The average speed of the vehicles on Route 562 was assumed to be greater than 35 to 45 miles per hour (a study siting criterion), since the posted speed limit on this section is 50 miles per hour.

2.3 SITE CHARACTERISTICS

The abandoned theatre site is used as a holding area for newly manufactured General Motors automobiles (upwind of the monitoring site); for this reason, the entire facility was secured by a fence with a locked gate. Utilities were available on site for monitor operation.

As shown in Figure 2-3, the site provides unobscured exposure to the Route 562 traffic flow, with no topographical interruptions.

Ten high-volume (Hi-Vol) ambient air samplers were operated at the site. The samplers were placed at three elevations and three setback distances from the roadway. One Hi-Vol was used as a control. The control was co-located at the second setback distance and the middle elevation.

Setback distances were measured from the north edge of the four-lane divided road. No attempt was made to measure Hi-Vol setback distances from individual lanes. The prevailing meteorology, together with the effects of traffic volume and speed, were assumed to keep the particulates airborne such that contributions from all four lanes could best be measured from the north edge of Route 562.

2.4 LOCATION OF MONITORS

Three towers, each with three tiers at 1.1, 6.3, and 10.5 meter heights were constructed and oriented as shown in Figure 2-4. Each tier provided a secure platform for at least one Hi-Vol sampler. Tower No. 1 was located 2.8 meters from the road. The third tier included instruments to measure wind

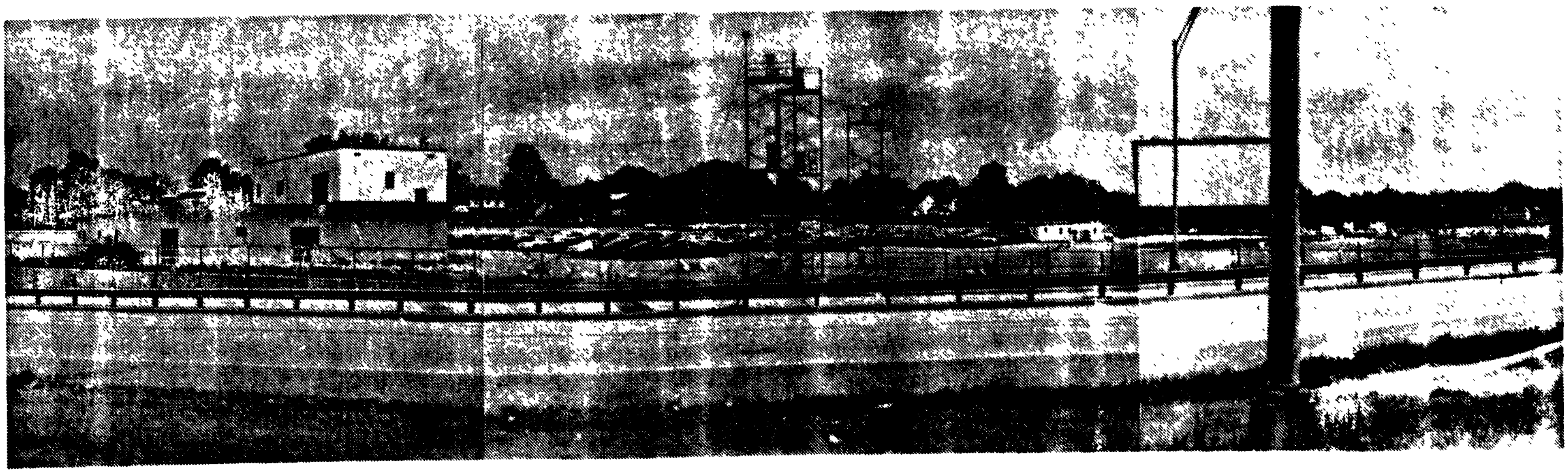


Figure 2-3. Photograph of sampling location showing monitors situated on towers.

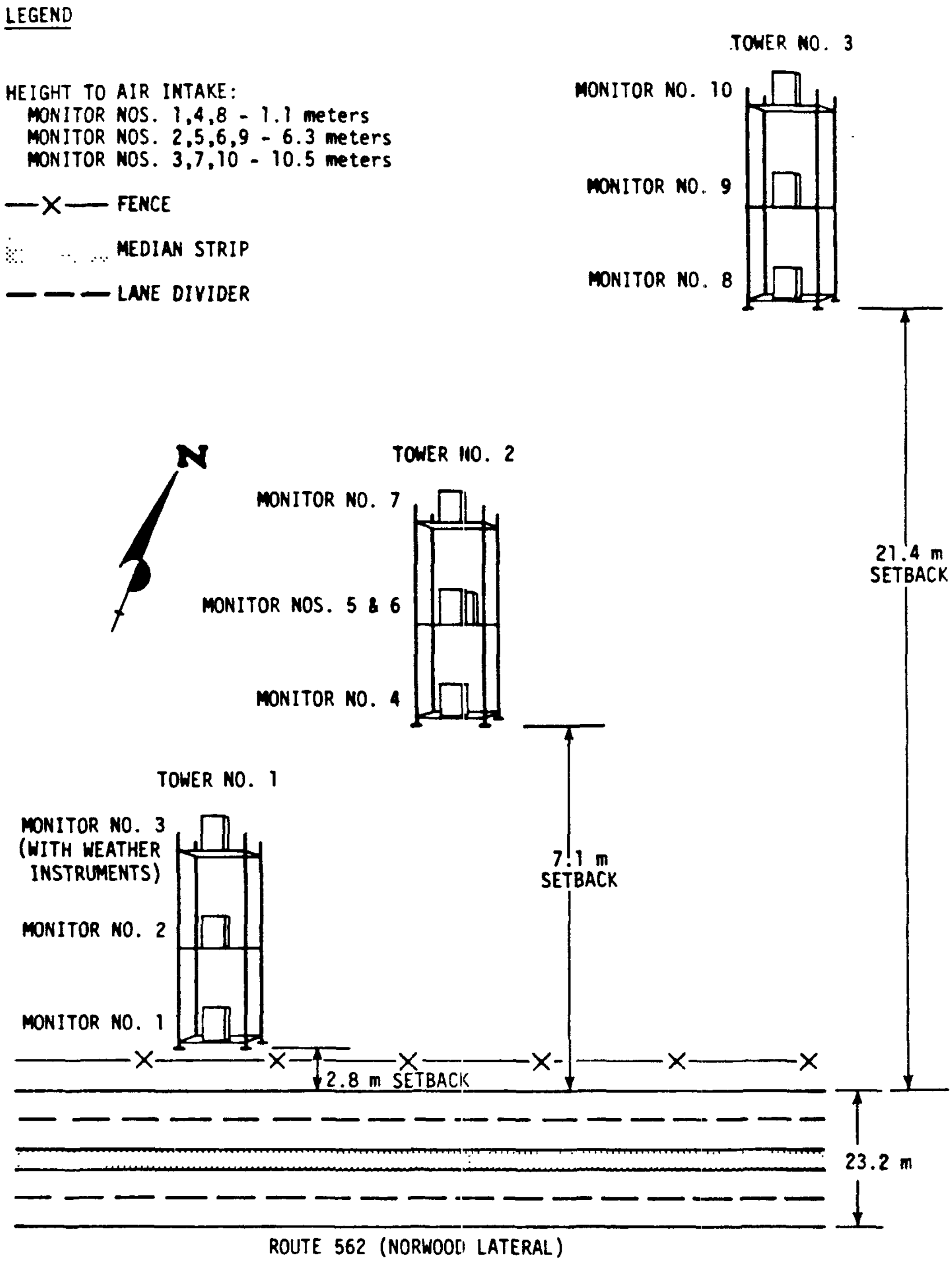


Figure 2-4. Schematic of sampling locations.

speed and direction. Tower No. 2, set 7.1 meters from the north edge of the road, held four Hi-Vol monitors. Placement was the same as on Tower No. 1, except that the second tier (6.3 meters above ground) held two samplers, one of which was used as a control. The filters in the control sampler were handled exactly like the filters of the other nine samplers, but no power was supplied to the Hi-Vol. The third tower was 21.4 meters from the road.

2.5 SAMPLING PROCEDURE

The filter media used in this study were Schleicher and Schuell No. 1 HV of spectro quality grade. During each of the 21 consecutive sampling days, at approximately 10:00 a.m., ten filters from the previous 24-hour sampling period were removed from the filter housing and replaced with unexposed filters. Hi Vols were calibrated and operated as specified in the Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II.[8] The exposed filters were then placed in an envelope and taken to the laboratory for analysis. Each filter was weighed twice and handled according to the procedures described in the Quality Assurance Handbook.[8] As a control in the laboratory, a laboratory filter blank was included daily and was handled in the same manner as the other filters. The laboratory blank provided information on the background lead levels for this type of filter. Additionally, the EPA supplied 20 audit filter strips with known lead content, which were also analyzed. Sampling and analysis quality assurance data are included in Appendix A.

As indicated earlier, the measurements of wind speed and direction were obtained from instruments located atop the third tier of Tower No. 1. This information was recorded continuously throughout the study on a strip chart. The stripchart data were then reduced to hourly readings.

2.6 LABORATORY PROCEDURE

The laboratory procedure involved gravimetric analysis of all filters for particulate matter with a Torbal EA-1 AP analytical balance. The filters were equilibrated in a controlled environment of 20° to 25°C ±3 percent and relative humidity of less than 50 ±5 percent for at least 24 hours before weighing. When equilibration was reached, the filters were weighed immediately after removal from the controlled environment. Each filter was tare and gross weighed twice. If the difference between the weighings exceeded the requirements specified in the Quality Assurance Handbook[8] the filters were weighed again. The original and check weighings were performed by different analysts.

After the filters were weighed the lead fraction of the particulate sample was analyzed with a Perkin-Elmer Model 560 atomic absorption spectrophotometer. Samples were prepared by a hot extraction procedure as described in the Quality Assurance Handbook.[8] The filters were digested in batches of 25, and all samples were analyzed for lead on the same day. Ten percent of the samples were analyzed in duplicate, including the laboratory and field blanks. Strips measuring 1.9 by 20.3 cm were cut from the exposed filter. Lead normally is considered to be uniformly distributed across a filter.[8,9,10] This has not proved true, however, in measurement of roadside emissions.[9,11] Therefore, several cuttings were made at various locations on the filter.

SECTION 3

RESULTS

Despite efforts to place the monitoring site at the point of optimum impact relative to wind direction, Figure 3-1 indicates that the overall impact was primarily from the southwest, west, and west-northwest rather than the southeast, the direction toward which the monitors were oriented. The monitors were oriented southeast to catch the full impact of the plume from the nearest traffic lane. The intent was to maximize lead emission impact as opposed to providing data to characterize traffic emissions.

There were no days during the study when the wind was blowing directly toward the monitoring site with appreciable speed (daily average in excess of 1.4 meters per second).

3.1 AVERAGE TOTAL SUSPENDED PARTICULATES

Figure 3-2 depicts the average 24-hour concentration of total suspended particulate matter (TSP) obtained from each of the field monitors. The average TSP concentration decreased with increasing elevation of the monitors at each setback distance. For all three setback distances the TSP concentration is highest at the lowest elevation (1.1 meters). This is the position nearest the vehicle emission point and closest to the road level where reentrained dust can be picked up. The average particulate level at ground level is highest at the monitor nearest the roadway, and it decreases with distance from the roadway. At an elevation of 6.3 meters, average particulate concentrations from the sampler on the second tower (7.1 meters setback) were higher than that at the 2.8 meter setback. The sampler at 6.3 meters elevation and 21.4 meters setback distance recorded lower average particulate concentrations than did the sampler setback 7.1 meters at the same elevation. It may be that the site nearest the roadway was located too close to the source for the elevated monitors to collect the maximum portion of the

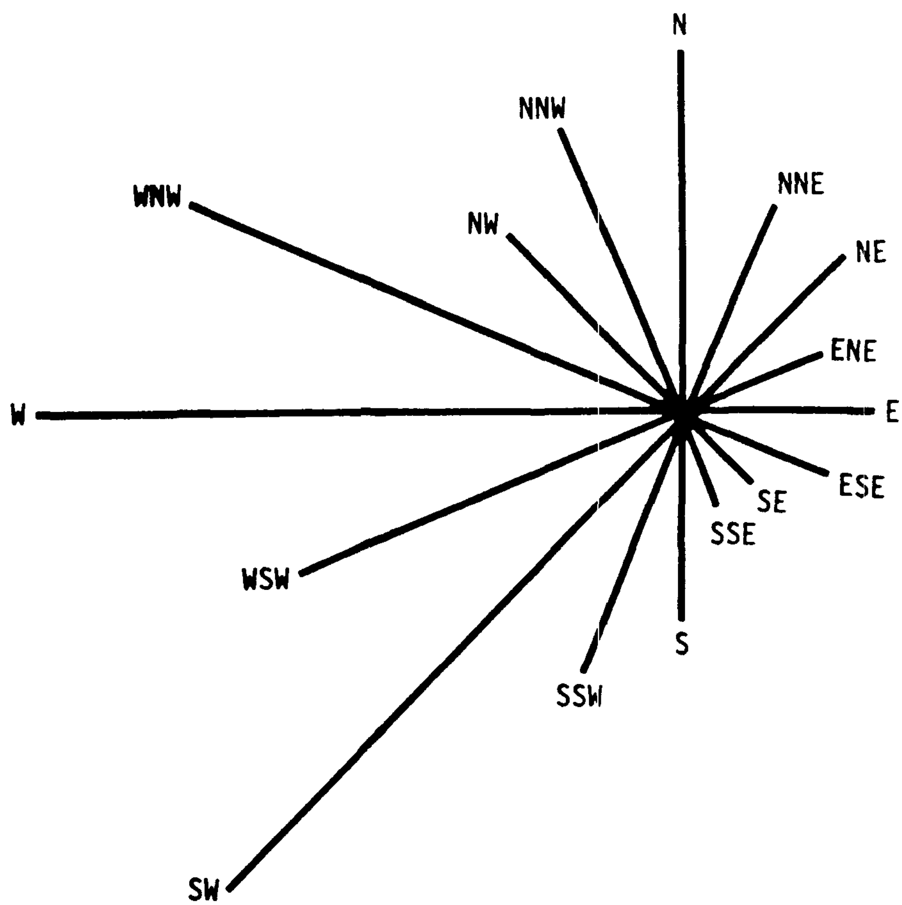


Figure 3-1. Wind rose indicating frequency of hourly average wind direction.

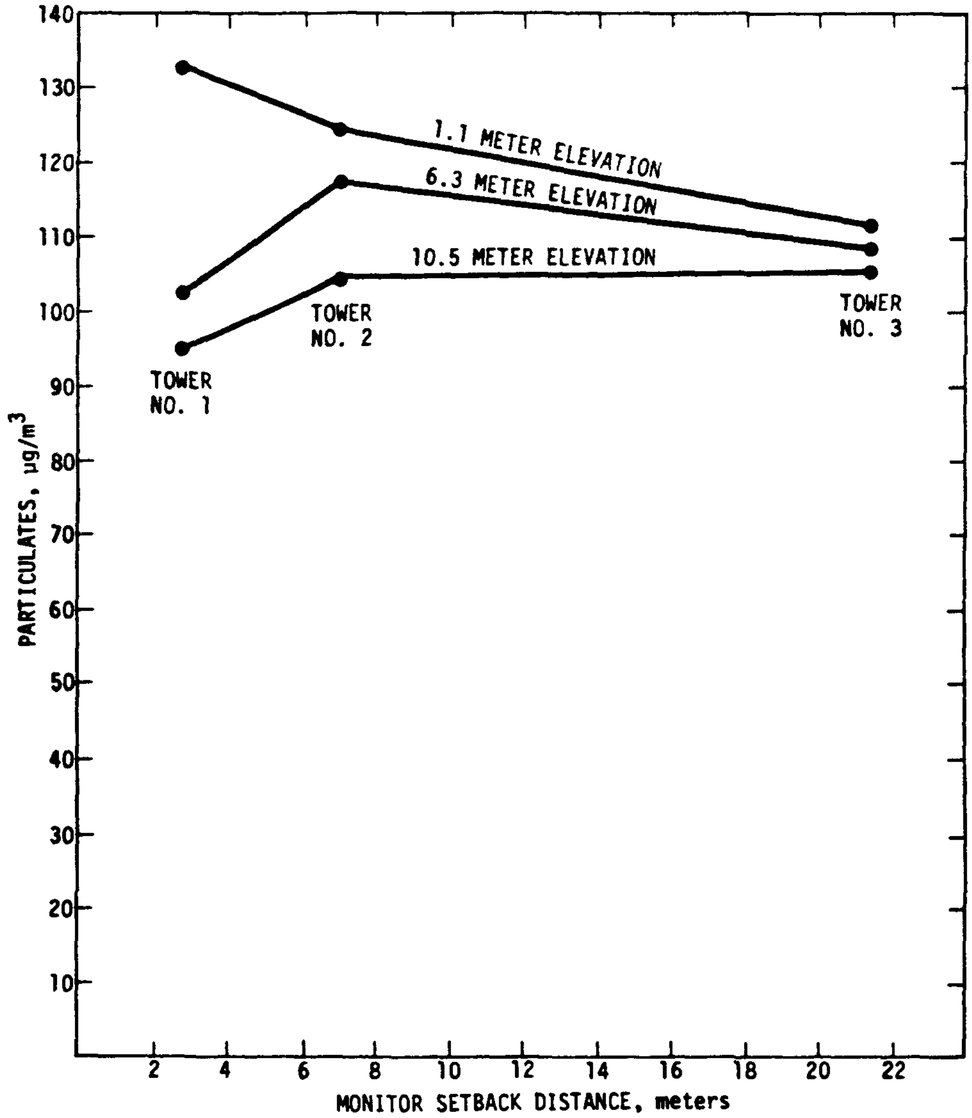


Figure 3-2. Average 24-hour concentration of total suspended particulates at various elevations and setback distances.

dispersing plume of traffic emissions. The 7.1 meter setback may have been in a better position to catch a larger portion of the dispersing plume. The average concentrations at an elevation of 10.5 meters indicate a slight increase between 1.1 and 7.1 meters setback distance, but remained virtually unchanged between 7.1 and 21.4 meters. Tables 3-1, 3-2, and 3-3 show the 24-hour TSP and lead concentrations at three elevations and at 2.8 meters, 7.1 meters, and 21.4 meter setbacks, respectively.

3.2 AVERAGE LEAD CONCENTRATIONS

The average 24-hour concentrations of lead are plotted in Figure 3-3. Supporting data are in Tables 3-1, 3-2, and 3-3. All of the measured concentrations of lead were adjusted to account for a mean background lead concentration on the filters. This was done by analyzing laboratory blanks for each day of the sampling program. Results from duplicate filter analysis for lead indicated a mean coefficient of variation of only 0.044 (4.4%) for the exposed filters.

As was the case with TSP, the highest lead concentrations for all setback distances were at 1.1 meters elevation. The data show that lead concentrations are higher at the lower elevations for each setback distance.

The average concentrations at both the 6.3 meter and the 10.5 meter elevations decrease slightly between the 7.1 meter and the 21.4 meter setbacks. These concentration gradients are less than for the 1.1 meter elevation. The average lead concentrations as a function of height do not converge as rapidly with increased distance from the road as they did for TSP.

The data also show that the concentrations at both the 6.3 and 10.5 meters elevation are lower at the 2.8 meters setback than for the 7.1 meters setback. The wind speed, wind direction, and turbulence created by the vehicular traffic are not sufficient to transport as many of the lead particles to the monitors at 6.3 and 10.5 meters elevation close to the roadway (2.8 meters) as farther from the roadway (7.1 and 21.4 meters). The concentrations at the 1.1 meter elevation show the normal decreasing trend as the distance from the roadway is increased.

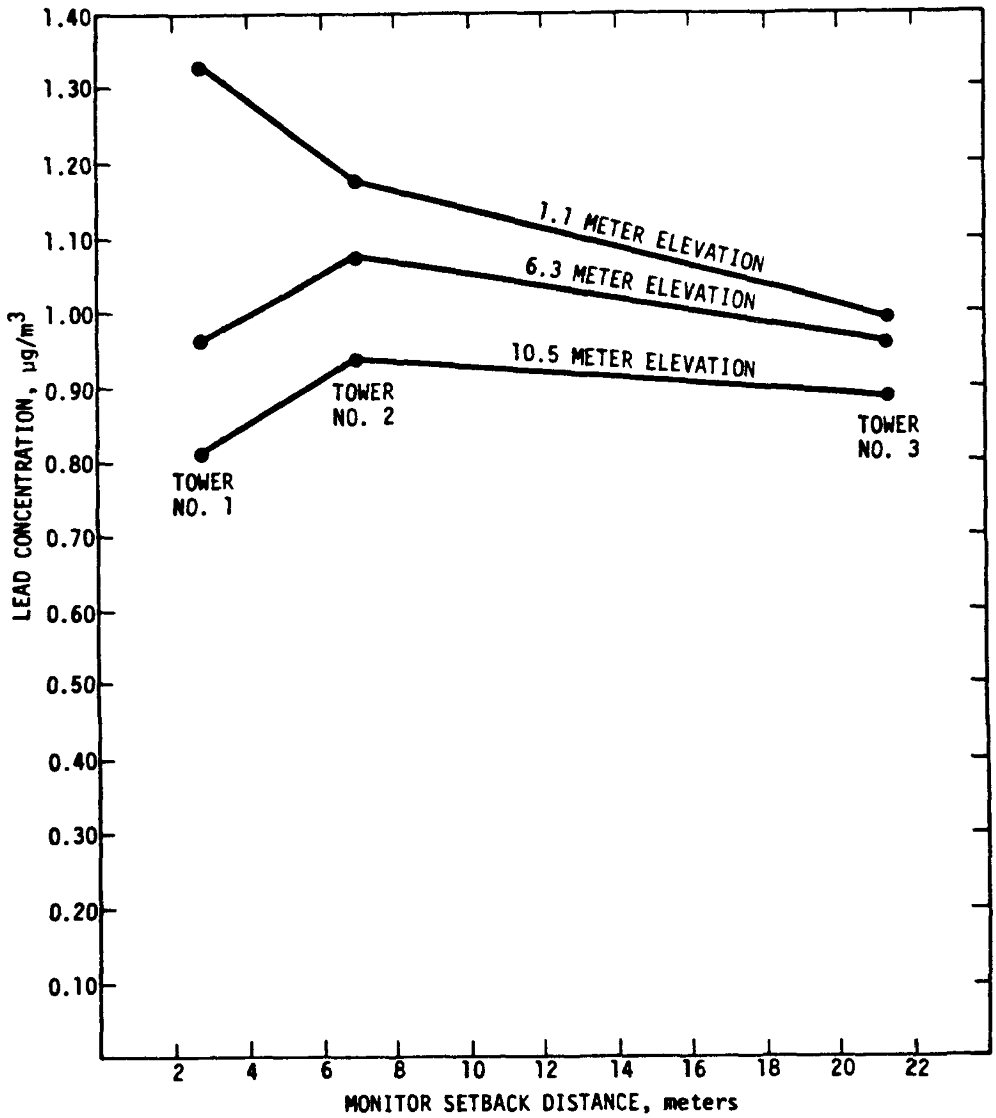


Figure 3-3. Average 24-hour concentration of lead at various elevations and setback distances.

TABLE 3-1. TOTAL SUSPENDED PARTICULATE AND LEAD CONCENTRATIONS AT THREE HEIGHTS AND 2.8 METERS SETBACK FROM THE ROAD

Date	Concentration ($\mu g/m^3$)					
	TSP			Lead		
	1.1 m	6.3 m	10.5 m	1.1 m	6.3 m	10.5 m
4/17/80	79	63	63	0.64	0.43	0.41
4/18/80	125	105	113	2.45	1.98	2.11
4/19/80	124	95	97	2.30	1.71	1.56
4/20/80	79	63	63	0.69	0.53	0.42
4/21/80	124	103	57	1.98	1.35	0.77
4/22/80	159	101	97	1.08	0.51	0.32
4/23/80	121	96	94	0.70	0.59	0.51
4/24/80	119	74	68	1.03	0.53	0.38
4/25/80	100	86	91	0.41	0.28	0.28
4/26/80	80	72	72	0.18	0.18	0.19
4/27/80	89	61	54	1.31	0.59	0.11
4/28/80	86	59	53	0.97	0.60	0.40
4/29/80	127	93	61	1.80	1.27	0.83
4/30/80	122	92	89	0.75	0.55	0.49
5/1/80	145	124	121	1.53	1.24	1.14
5/2/80	199	166	160	2.49	1.99	1.75
5/3/80	157	136	131	1.97	1.64	1.64
5/4/80	182	158	156	2.28	2.13	1.94
5/5/80	209	139	114	1.33	0.71	0.35
5/6/80	202	160	143	0.87	0.66	0.73
5/7/80	162	120	104	1.09	0.62	0.70
$\bar{x}$	133	103	95	1.33	0.96	0.81

TABLE 3-2. TOTAL SUSPENDED PARTICULATE AND LEAD CONCENTRATION AT THREE HEIGHTS AND 7.1 METERS SETBACK FROM THE ROAD

Date	Concentration ($\mu g/m^3$)					
	TSP			Lead		
	1.1 m	6.3 m	10.5 m	1.1 m	6.3 m	10.5 m
4/17/80	77	72	-	0.56	0.44	-
4/18/80	125	125	116	2.33	2.13	2.03
4/19/80	115	112	101	2.18	1.72	1.78
4/20/80	82	74	65	0.71	0.57	0.38
4/21/80	118	120	108	1.49	1.67	1.65
4/22/80	160	118	99	1.01	0.51	0.32
4/23/80	112	111	96	0.72	0.70	0.52
4/24/80	112	86	70	0.68	0.53	0.37
4/25/80	98	100	95	0.37	0.40	0.30
4/26/80	83	83	76	0.22	0.43	0.31
4/27/80	83	71	57	1.06	0.94	0.60
4/28/80	81	71	55	0.76	0.63	0.34
4/29/80	115	101	85	1.36	0.95	0.65
4/30/80	113	104	91	0.82	0.59	0.42
5/1/80	138	134	123	1.14	1.12	1.42
5/2/80	197	197	163	2.26	2.27	1.69
5/3/80	150	162	143	1.85	1.92	1.91
5/4/80	177	183	160	2.16	2.35	2.22
5/5/80	189	164	124	1.09	0.78	0.41
5/6/80	183	181	149	0.97	0.98	0.61
5/7/80	142	135	113	0.68	0.89	0.71
$\bar{x}$	126	119	104	1.16	1.07	0.93

TABLE 3-3. TOTAL SUSPENDED PARTICULATE AND LEAD CONCENTRATION AT THREE HEIGHTS AND 21.4 METERS SETBACK FROM THE ROAD

Date	Concentration ($\mu g/m^3$)					
	TSP			Lead		
	1.1 m	6.3 m	10.5 m	1.1 m	6.3 m	10.5 m
4/17/80	70	70	68	0 39	0.39	0.41
4/18/80	120	118	114	2.18	2.22	2.07
4/19/80	103	105	101	1.91	1.67	1.68
4/20/80	68	70	66	0.53	0.42	0.44
4/21/80	108	113	107	1.53	1.57	1.49
4/22/80	131	113	104	0.71	0.52	0.36
4/23/80	95	94	95	0.50	0.50	0.48
4/24/80	90	80	72	0.59	0.46	0.36
4/25/80	96	98	96	0.28	0.29	0.31
4/26/80	64	80	78	0.26	0.34	0.31
4/27/80	58	67	61	0.90	0.83	0.62
4/28/80	67	60	55	0.68	0.56	0.39
4/29/80	96	91	87	1.03	0.79	0.86
4/30/80	101	95	95	0.63	0.54	0.43
5/1/80	123	129	129	1.16	1.18	1.20
5/2/80	202	179	169	1.85	2.12	1.75
5/3/80	141	151	157	1.81	1.85	1.96
5/4/80	168	168	166	1.88	1.82	1.98
5/5/80	161	142	133	0.85	0.77	0.52
5/6/80	161	156	154	0.69	0.74	0.60
5/7/80	126	118	117	0.90	0.83	0.77
$\bar{x}$	112	109	106	1.01	0.97	0.90

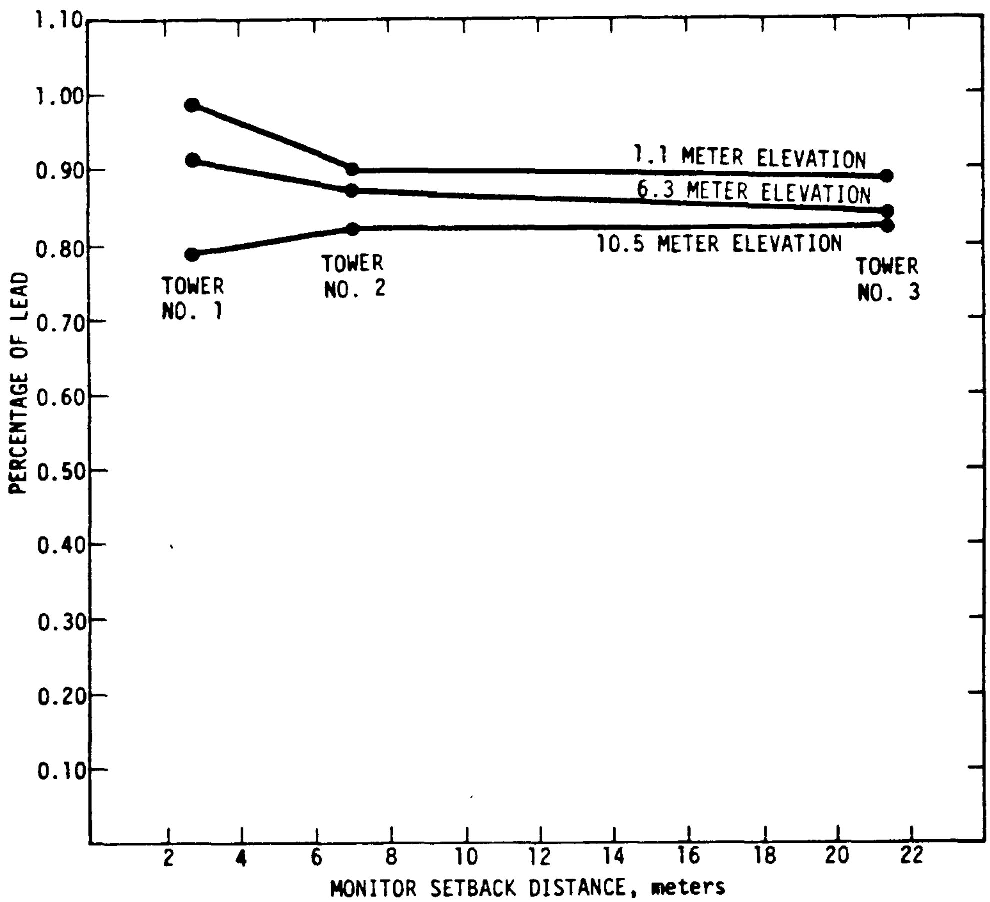


Figure 3-4. Average percentage of lead in total suspended particulate samples at three elevations and three setback distances.

The data show that sampler height is critical in terms of concentration range uniformity closer to the roadway (2.8 meters setback), but it becomes less critical between 7.1 meters and 21.4 meters setback.

3.3 LEAD AS A PERCENTAGE OF TOTAL SUSPENDED PARTICULATES

The lead fraction as a percentage of the particulate concentration was calculated for all samples. The results are illustrated in Figure 3-4.

A 1977 report by PEDCo[3] indicated that the average fractions of lead in particulate samples were 1 to 2 percent, with none less than 0.2 percent and none higher than 5.0 percent. The data in the current study indicate an average of 0.80 to 1.00 percent. The highest percentage of lead was measured at monitors located at 1.1 meter elevation. Figure 3-4 indicates that lead as a percent of TSP decreases with elevation. Distance from the roadway appears to have minimal effect on lead concentration expressed as percent of TSP concentration.

3.4 RELATIVE LEAD CONCENTRATIONS

Figure 3-5 shows the effects of locating lead monitors in positions that are less than optimal for measuring maximum concentrations, where breathing level (1.1 meters elevation) would be considered optimal. The average concentrations at elevations of 6.3 and 10.5 meters are expressed relative to the concentrations at 1.1 meters for each of the three setback distances. At both elevations the maximum relative lead concentration is obtained when the setback distance is 21.4 meters. Relative concentrations at setback of 7.1 meters from the roadway and less than 6.3 meters elevation represented 96 percent of the maximum. Relative concentrations at 21.4 meters from the roadway and 10.5 meters elevation represented 89 percent of the maximum lead concentration.

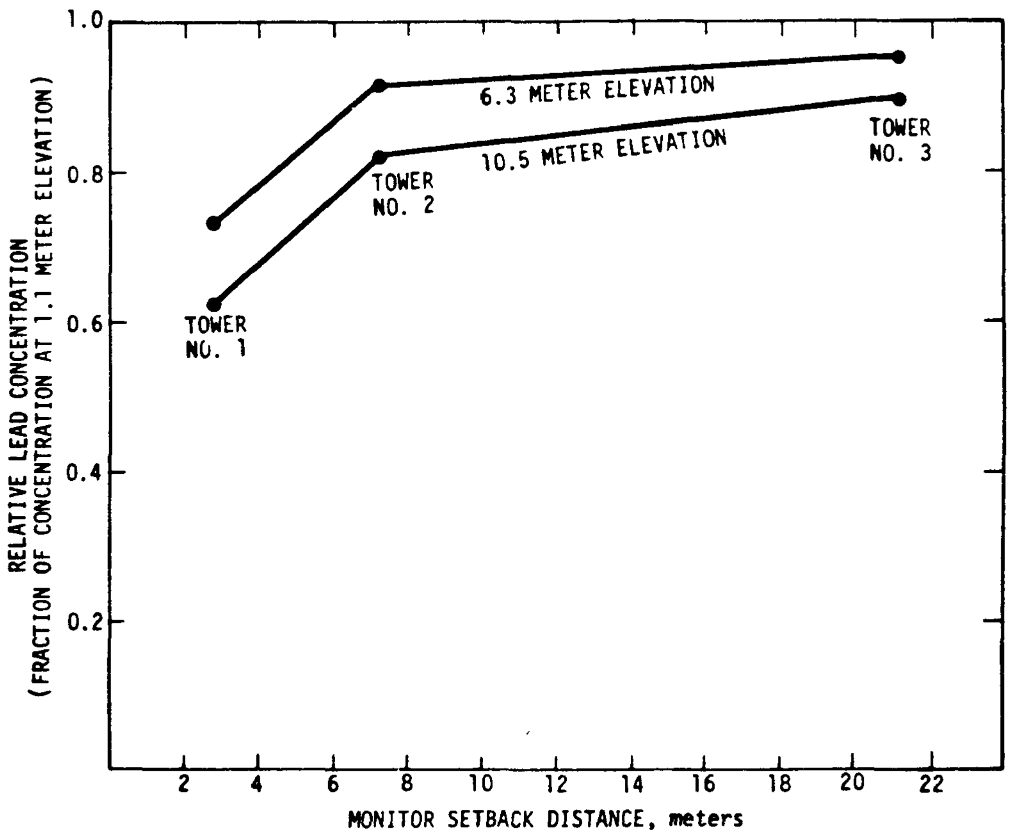


Figure 3-5. Average 24-hour concentration of lead at the ground level monitor compared to concentrations at elevated monitors.

SECTION 4

CONCLUSIONS

The data from this study show that both TSP and lead concentrations are greatest at the 1.1 meter breathing level height for each of three setback distances studied. The TSP and lead concentrations at three vertical heights are different at each setback distance from the roadway. The concentration differences between each height are greater between 2.8 and 7.1 meters setback than between 7.1 and 21.4 meters.

The EPA performed a statistical analysis of the monitoring results (Appendix B) to determine if the data support the siting criteria for microscale and middle scale lead monitoring stated in the regulation. The criteria allow microscale monitors to be placed between 2 and 15 meters from the roadway and at a vertical height of 2 to 7 meters. Monitors at middle scale sites should be between 15 and 100 meters from the roadway and at 2 to 15 meters high. The analysis concludes that the siting criteria for both monitoring sites are reasonable both in terms of height and setback distance.

REFERENCES

1. Federal Register, Vol. 43, No. 194, Thursday, October 5, 1978, pp. 46246-46247.

2. Danies, R. H., H. Motto, and D. M. Chilko. Atmospheric Lead: Its Relationship to Traffic Volume and Proximity to Highway. Environ. Sci. Technol. 4 (4):318-322, 1970.

3. PEDCo Environmental, Inc. Lead Analysis for Kansas City and Cincinnati. Environmental Protection Agency, Contract 68-02-2515. June 1977.

4. Bryan, R. J., R. J. Gordon, and H. Menck. Comparison of High Volume Air Filter Samples at Varying Distances from Los Angeles Freeways, Presented at the 68th Annual Meeting of the Air Pollution Control Association, Chicago. June 24-28, 1973.

5. Barltrap, D., and C. D. Strelow. Westway Nursery Testing Project. Report to the Greater London Council. August 1976.

6. Creason, J.P., et al. "Roadside Gradients in Atmospheric Concentrations of Cadmium, Lead, and Zinc," in Trace Substances in Environmental Health, V. 5., A Symposium, D.D. Hemphill, ed. U. of Missouri, 1972.

7. Record, F., et al. Philadelphia Particulate Study, G.C.A. Report to EPA, Report No. GCA-TR-78-02-6, 1978.

8. U.S. Environmental Protection Agency Report No. 600/4-77-027a, May 1977. Quality Assurance Handbook for Air Pollution Measurement Systems Volume II.

9. Scott, R. K., et al. Atomic Absorption and Optical Emission Analysis of NASN Atmospheric Particulate Sampler for Lead. Environ. Sci. and Technol. 10, 877-880, 1976.

10. Zdrojewaki, A., et al. The Accurate Measurement of Lead in Airborn Particulates. Inter. J. Environ. Anal. Chem. 2, 63-77, 1972.

11. U.S. Environmental Protection Agency Report No. 600/4-77-034, June 1977. Los Angeles Catalyst Study Symposium. pp. 223.

APPENDIX A

LABORATORY PROCEDURES

The methods described in the following references were used to determine the total suspended particulate (TSP) and lead (Pb) concentrations:

1. Reference Method for the Determination of Suspended Particulates in the Atmosphere. 40 CFR 50.11, Appendix B, July 1, 1975.

2. Reference Method for the Determination of Lead in Suspended Particulate Matter Collected from Ambient Air. 43 CFR 194, Appendix G, October 5, 1978.

The Quality Assurance procedures used are described in:

Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II. U.S. EPA Publication No. EPA-600/ 4-77-027a, May 1977 (The lead analysis procedure is in draft form).

The following deviations were made from the published QA procedures. All procedures are more rigorous than required by the manual.

1. Schleicher & Schuell Type 1-HV spectoquality filters were used.

2. All filters were tare and gross weighed twice. The original and check weighings were performed by different analysts.

3. 10% of the samples were analyzed in duplicate. 10% of each of the field and lab blanks were also analyzed in duplicate. Each of the 9 sites had at least 2 duplicates run several days apart.

4. 20 audit strips of known Pb content, supplied by the U.S. EPA, were also analyzed.

The filters were digested in batches of 25. The hot acid method described in the Reference Method was used. Table A-1 details the distribution by filter type of each batch. All samples were analyzed for lead on the same day.

Summaries of the values obtained from the analyses of the field blanks, lab blanks, and audit strips are attached. All lead values reported have been corrected for the 23 μg Pb/filter of the lab blank.

The audit strip summary shows decreasing recovery of Pb with increasing concentration. No sample, however, contained more than 500 μg Pb per strip (1/12 filter), and most contained less than 200 μg Pb.

The summary of replicates shows a mean coefficient of variance of 0.044 (4.4%).

LABORATORY QUALITY CONTROL FOR SPECIAL MONITORING PROGRAM FOR LEAD PN 3366-G

Each filter for this project was prepared according to method 87 except that each filter was weighed at least twice before sampling. Each day samples consisted of a set of 11 filters - 9 sampling filters, 1 laboratory blank and 1 field blank.

All filters were equilibrated, weighed, and then stored in their original container. The filters were stored and loaded in a clean area prior to their delivery to the sampling site. The field blank was placed in a shelter similar to those used for the samplers.

Upon return of each set of recovered filters to the laboratory a clean filter from the stock was added as a laboratory blank. Each set of filters was delivered and logged in the laboratory using the standard procedure.

Each set of filters was equilibrated and weighed according to method 87 except that each filter was weighed at least twice. When all filters in a set had been weighed and met the specified criteria, they were prepared for lead analysis.

Lead analysis was done according to the method list in the Q.A. Manual Volume II for Ambient Methods. All eleven filters in the set were analyzed along with one audit strip for Pb. One sample filter was extracted and analyzed in duplicate.

TABLE A-1. SUMMARY OF LABORATORY QUALITY ASSURANCE SAMPLE ANALYSIS

Batch No.	1	2	3	4	5	6	7	8	9	10	11	12	Totals
Samples	17	17	18	18	18	17	17	18	18	18	17	4	197
Sample repeats	2	2	2	1	1	2	2	2	1	1	2	2	20
Field blanks	1	2	2	3	2	1	2	2	2	2	2	0	21
Field blank repeats	1					1							2
Lab blanks	2	1	2	3	2	2	1	2	2	2	2	0	21
Lab blank repeats		1					1						2
Audit strips	2	2	1	2	2	2	2	1	2	2	2	0	20
Sample repeats from station #	1,2	3,4	5,6	7	8	9,1	2,3	4,5	6	7	8,9	5,7	
Total	25	25	25	27	25	25	25	25	25	25	25	6	283

APPENDIX B
ANALYSIS OF ROADWAY LEAD DATA USING ANALYSIS OF VARIANCE TECHNIQUES

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The lead data, collected by PEDCo Environmental, Inc. in the report, Field Study to Determine Spatial Variability of Lead from Roadways[1], have been reanalyzed using the Analysis of Variance (ANOVA). The data were collected by PEDCo Environmental to perform a limited field monitoring study to determine the relative horizontal and vertical lead distribution in support of the monitoring siting ranges in the Part 58 regulation. The application of the ANOVA to the lead and TSP data is presented, along with the results of the analysis.

Statement of Objectives

(1) To determine whether there are significant differences in lead concentrations measured at varying setback distances from roadways and at different vertical heights.

(2) If there is a difference between setback distances or vertical heights or combinations of both, we wish to determine the optimum location for monitoring the expected maximum lead concentrations along roadways with consideration being given to safety, vandalism, and averaging time of the standard.

Descriptions of the Experiment

The experiment is a factorial design, where the setback distances (L_i) and vertical heights (H_j) are fixed and the effects of week (W_k) and day (D_l) are random. The location for the experiment was the parking area of an abandoned drive-in theatre on State Route 562, in the Norwood area of Cincinnati. Three towers, each with three tiers at 1.1, 6.3, and 10.5 meter heights (H_j), were constructed. One high-volume sampler for measuring TSP and lead was located at each tier of each tower. The towers were located at setback distances of 2.8, 7.1, and 21.4 meters from the road. Both lead and TSP data were collected for three weeks between April 17 and May 7, 1980. The procedures taken to ensure data quality are described in the report and will not be discussed here.

Mathematical Model

An additive model was used to describe the experimental design as follows:

$$X_{ijkl} = \mu + L_i + H_j + LH_{ij} + W_k + LW_{ik} + HW_{jk} + D_l + WD_{lk} + E_{ijkl}$$

where X_{ijkl} = the lead or TSP measurement

μ = the overall average

L_i = the effect due to setback distance

H_j = the effect due to vertical height

LH_{ij} = the effect due to the interaction of setback distance and vertical height

W_k = the effect due to differences between weeks

LW_{ik} = the effect due to the possible interaction between setback distances and weeks

HW_{jk} = the effect due to the possible interaction between vertical heights and weeks

D_l = the effect due to days

WD_{lk} = the effect due to the possible interaction between weeks and days

E_{ijkl} = the undesigned variabililty or random error

The term E_{ijkl} is made up of the following 2 and 3 way interactions which were assumed not to exist: LHW_{ijk}, LD_{il}, HD_{jl}, LHD_{ijl}, LWD_{ikl}, HWD_{jkl} and $LHWD_{ijkl}$. It must be kept in mind that the authors of this Appendix did not design the original experiment, but instead applied the ANOVA after the experiment had been run and the data collected.

Results

In performing the ANOVA, no tranformation of the data was taken. The data were assumed to be approximately normally distributed. The ANOVA for lead is shown in Table 1 and the ANOVA for TSP is shown in Table 2. In both analyses, all the sources of variation were statistically different from 0.0 with the exception of the interactions of setback distance by week and vertical height by week. The mathematical model explains 95.5% of the lead variability and 95.3% of the TSP variability.

Of particular importance is the result that there is a significant interaction between setback distance and vertical height. This is illustrated in Figures 1 and 2 for lead and TSP, respectively, which summarize the interactions by calculating the means associated with each combination of setback distance and vertical height, along with their 95% confidence intervals. Where the confidence intervals overlap, the means are not significantly different from one another. Because multiple comparisons are being made, the Just Significant Confidence Interval (JSCI) has been calculated using the Tukey "q" statistic.[1]

Generally, at each setback distance, the mean of lead or TSP decreases as the vertical height increases. At the setback distance of 2.8 meters, the mean associated with a vertical height of 1.1 meters is the highest recorded and is significantly different from the recorded means at the vertical heights of 6.3 and 10.5 meters. (The confidence intervals do not overlap.) As the vertical height increases to 10.5 meters, the lowest mean is recorded. At each setback distance, the decrease in both lead and TSP levels as the vertical height increases, is different with the greatest drop shown at the setback distance closest to the roadway (2.8 meters). This difference, in the relative change at each of the setback distances, is why the interaction exists.

An examination of Figures 1 and 2 shows that multiple comparisons can be made. Of particular interest is whether or not this analysis supports the EPA recommended siting criteria for the microscale and middle scale roadway sites to measure the area of maximum lead concentration. The EPA recommendation for the microscale sites is that the lead monitor be placed between 5 and 15 meters from the roadway with a vertical height of 2 to 7 meters. The recommendation for the middle scale sites is that the lead monitor must be placed between 15 and 100 meters, depending on the average daily traffic, with a vertical height of 2 to 15 meters. From Figure 1, the maximum concentration is observed at the monitor closest to the roadway (setback distance of 2.8 meters and vertical height of 1.1 meters). In some cases it may not be permissible to establish such a site or it may not be practical to locate the monitor so close to the roadway, because of potential vandalism, and problems in servicing a monitor so close to the flow of traffic.

Eliminating the monitor closest to the roadway, the next highest recorded mean of ambient lead levels occurs at a setback distance of 7.1 meters and a vertical height of 1.1 meters. This mean is not significantly different from the mean of the ambient level recorded at the same setback distance, but at the higher vertical height of 6.3 meters.

The mean recorded at this combination of vertical height (6.3 meters) and setback distance (7.1 meters) is of interest, because it is the only monitor located within the EPA criteria for the microscale roadway type site. It is important to note that the confidence interval about the mean of this monitor overlaps the confidence intervals of the means of all other monitors with the exception of the means of the monitors located at a setback distance of 2.8 meters and vertical heights of 1.1 meters (the highest mean) and 10.5 meters (the lowest mean).

All three monitors at 21.4 meters from the roadway were located within the EPA criteria for the middle scale roadway type site. The means for these monitors are not significantly different from each other since the confidence intervals of the means overlap. Also, it should be noted that these confidence intervals overlap the confidence interval of the mean of the monitor located at 7.1 meters from the road and 6.3 meters high.

Since the monitor closest to the roadway with the highest mean (vertical height of 1.1 meters) is not practical because of potential vandalism and problems in servicing a monitor so close to the flow of the traffic, the EPA recommended siting criteria for microscale and middle scale sites for distance from roads and height above ground are reasonable.

Reference

1. W.J. Dixon and F.J. Massey, Jr., Introduction to Statistical Analysis, 440-442, McGraw-Hill Book Co., Inc., New York (1957).

TABLE 1. ANOVA TABLE FOR LEAD

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic
Distance (L)	2	0.247	0.124	5.39*
Height (H)	2	2.729	1.365	59.35***
L x H	4	1.080	0.270	11.74***
Week (W)	2	19.005	9.503	413.17***
L x W	4	0.021	0.005	<1
H x W	4	0.101	0.025	1.09
Day (D)	6	15.925	2.654	115.39***
W x D	12	35.980	2.998	130.34***
Error	151	3.506	0.023	

* Probability less than 0.01

** Probability less than 0.001

*** Probability less than 0.0001

TABLE 2. ANOVA TABLE FOR TSP

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic
Distance (L)	2	1660.290	830.145	10.24**
Height (H)	2	15850.626	7925.313	97.78***
L x H	4	7141.353	1785.338	22.03***
Week (W)	2	168137.959	84068.979	1037.19***
L x W	4	81.719	20.430	<1
H x W	4	479.111	119.778	1.48
Day (D)	6	27471.217	4578.536	56.49***
W x D	12	29238.256	2436.521	30.06***
Error	151	12239.233	81.055	

* Probability less than 0.01

** Probability less than 0.001

*** Probability less than 0.0001

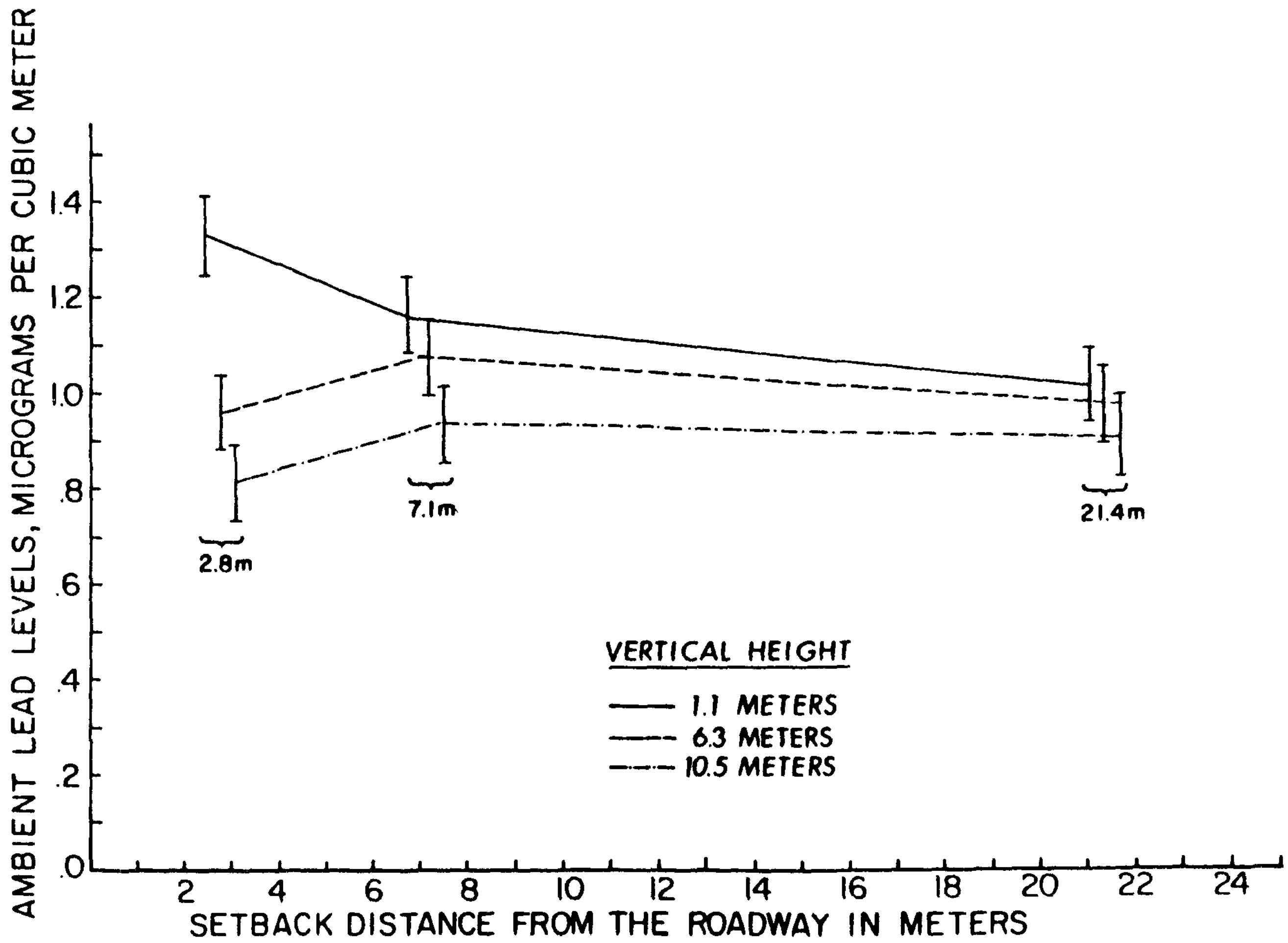

Figure 1. Arithmetic Means and 95 Percent Confidence Intervals for Combinations of Setback Distance and Vertical Height.

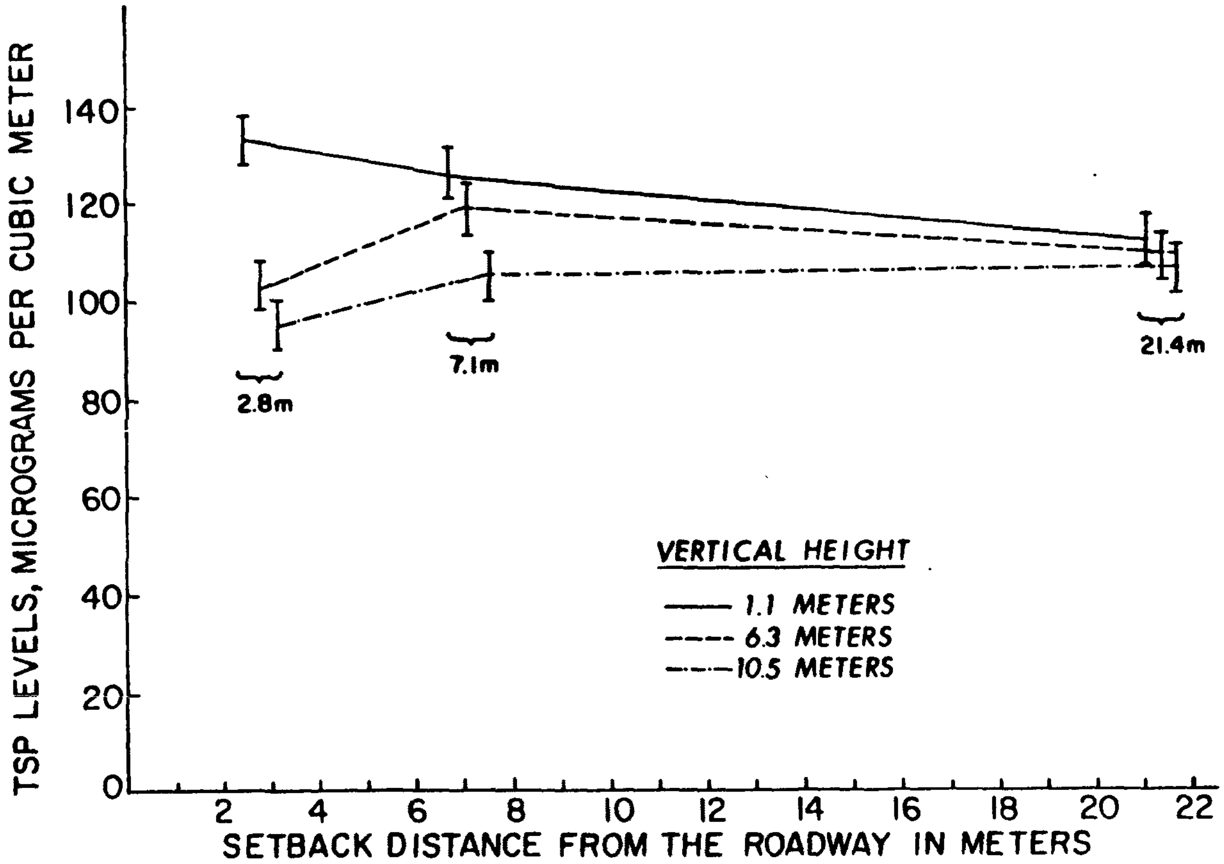

Figure 2. Arithmetic Means and 95 Percent Confidence Intervals for TSP Measurements for Combinations of Setback Distance and Vertical Height.

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16. ABSTRACT

A short-term field monitoring study was conducted to determine the horizontal and vertical lead distribution along roadways. Results are presented for three heights and three horizontal setback distances from roadways.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Lead Monitoring Horizontal and Vertical Lead Distribution Ambient Air Quality Measurements		10

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